LUBRICATING ENGINEER'S HANDBOOK

A REFERENCE BOOK OF DATA, TABLES AND GENERAL INFORMATION FOR THE USE OF LUBRICATING ENGINEERS, OIL SALESMEN, OPERATING ENGINEERS, MILL AND POWER PLANT SUPERINTENDENTS AND MACHINERY DESIGNERS, ETC.

BY

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THE AUTHOR
AFFECTIONATELY DEDICATES
THIS BOOK TO
A. T. B

PREFACE

CONSIDER, that not a spindle can turn without overheating and wear, nor the largest locomotive in the world move a heavy train, unless there is a lubricant provided to reduce the ever-present friction between the bearing surfaces, and the importance of the almost limitless field of " Lubricating Engineering " may be appreciated.

Of all the supplies used in the operation of power plants and industrial mills, lubricants and their practical application are the least understood.

Designers of machinery are interested in the subject of theoretical lubrication and its effect upon the design of machinery bearings.

Operating engineers are interested in the efficient and smooth running of the machines under their charge.

Owners and general managers are interested in lessening the cost of production. This may be accomplished by reducing the friction load of their plants, with the consequent reduction in power costs.

Purchasing agents are interested in the buying of lubricants suitable for use in their plants, at the lowest prices consistent with the quality and physical requirements demanded of these lubricants.

Lubricating oil salesmen of modern times are required to have a general knowledge of the working conditions met with in the various industries, a knowledge of the fundamentals of mechanical and electrical engineering, and a general knowledge of the manufacture and properties of petroleum and other oils and greases.

These are days of efficiency and keen business competition. The oil salesman who is in a position to assist his trade with practical and helpful information bearing upon the lubricating engineering of their equipment will obtain a far greater share of the business in his field than will result from his efforts if he overlooks this important asset.

Manufacturers of lubricants are interested in the marketing of standard brands of oils and greases, especially designed to meet the lubricating requirements of the trade. They are therefore interested in obtaining a concise description of the mechanical and physical conditions affecting the lubrication of the machinery of the various industries.

These conditions were so obvious to me when, as a mechanical engineer, I became associated with the oil business, that I began to collect data and keep a note-book. This data and such descriptions and tables as I have found to be of value to the trade have been included in this handbook, with the earnest desire that they may be found to be unbiased in their recommendations and of practical value in everyday work.

I desire to take this opportunity to thank the manufacturers and others who have kindly assisted me in the securing of much valuable information.

TABLE OF SYMBOLS

The following symbols and abbreviations are used in the text and are defined as follows:—

S. G. .... Specific Gravity.
B* .... Baumé Gravity.
Vis. .... Viscosity. (Unless otherwise stated, Saybolt Viscosity is intended.)
Say. .... Saybolt.
Fahr. .... Fahrenheit degrees.
C. .... Centigrade.
Fl. .... Flash-point in degrees Fahrenheit.
F. .... Fire-point in degrees Fahrenheit.
C. T. .... Cold Test in degrees Fahrenheit.
P. B. .... Refers to oils made from the so-called Paraffine Base Crudes.
A. B. .... Refers to oils made from the so-called Asphalt Base Crudes.

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LUBRICATING ENGINEER'S HANDBOOK

PART I

CHAPTER I

FRICTION

Description and Effect.—There is a tax which all operators of machinery must pay, whenever their machines are in motion, which may be called the Friction Tax.

Friction.—Friction can best be described as that force which resists the relative motion of one particle or body in contact with another particle or body and resists their sliding one on the other at the surfaces of contact.

Three Kinds of Friction.—There are three kinds of friction:

(*a*) Rolling friction between solids.

(*b*) Sliding friction between solids.

(*c*) Fluid friction between the particles of a fluid.

SOLID FRICTION

Kinetic Friction.—The frictional resistance between two bodies in contact when moving relatively to each other is called Kinetic Friction or Friction of Motion.

Laws of Sliding Friction.—The following laws govern the conditions of friction between dry and unlubricated surfaces:

(*a*) For small loads at low speeds, the friction between dry surfaces is proportional to the pressure between the surfaces.

(*b*) The friction between dry surfaces is not affected by the area of the surfaces, providing the pressure is constant. All sliding surfaces, no matter how carefully they may be finished, are known to consist of minute projections and depressions (see Fig. 1). When two surfaces are held in contact by any force, these projections and hollows on the contact faces interlock and resist sliding or relative motion.

Friction of Rest or Static Friction.—Friction of Rest or Static Friction

must be distinctly separated from Kinetic or Friction of Motion. It requires a greater force to start one surface sliding over another, than to maintain the sliding after the motion has begun. Therefore Static Friction exceeds Kinetic Friction.

Coefficient of Friction is Variable.—The value of the Coefficient of Friction for lubricated surfaces varies with the velocity, pressure, and temperature of the contact surfaces. If the two contact surfaces as shown in Fig. 1 are pressed together with an increased force or pressure, the various projections and depressions are more closely interlocked and therefore offer greater resistance to relative motion. This demonstrates

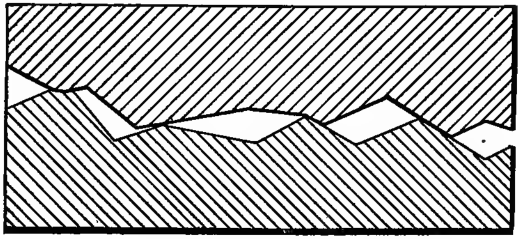


FIG. 1.—Magnified surfaces of contact.

that the friction is increased directly as the pressure. The Coefficient of Friction for any contact surfaces is the ratio of the maximum resistance of friction, to the normal or perpendicular pressure holding the surfaces together.

That is: F_c equals $\frac{R}{P}$, where R = Maximum Resistance to motion due to Friction. P = Normal force holding the surfaces together. F_c = Coefficient of Friction.

Rolling Friction.—The resistance offered to the rolling of a spherical or cylindrical body, across a plain or curved surface, is called Rolling Friction.

Cause of Rolling Friction.—The irregularities of the contact surfaces of even supposedly perfectly smooth plane and cylindrical bodies force the rolling body to lift itself over the minute projections, which resist the rolling action. This resistance is the cause of Rolling Friction.

FLUID FRICTION

Fluid Friction.—Fluid friction is of great importance in the study of lubrication. When the particles of a fluid are in motion and the outer

surfaces of the fluid are in contact with solid surfaces, the fluid body is divided into numerous layers within itself. The friction produced by the slipping of these layers composing the fluid over one another and by the "rubbing effect" between the fluid particles is called Fluid Friction.

Frictional Heat.—The energy consumed in overcoming kinetic frictional resistance is converted into heat. This heat is called Frictional Heat and may be considered a measure of the energy wasted in overcoming friction.

CHAPTER II

THEORY OF LUBRICATION

Lubrication.—Every part of a machine which slides or moves over another part instantly develops friction, and, unless the contact points or surfaces are separated by a film of lubricant, an excess of frictional heat and resistance will be developed.

Friction.—The friction of lubricated surfaces varies greatly with the character of the lubricant and the method of its application.

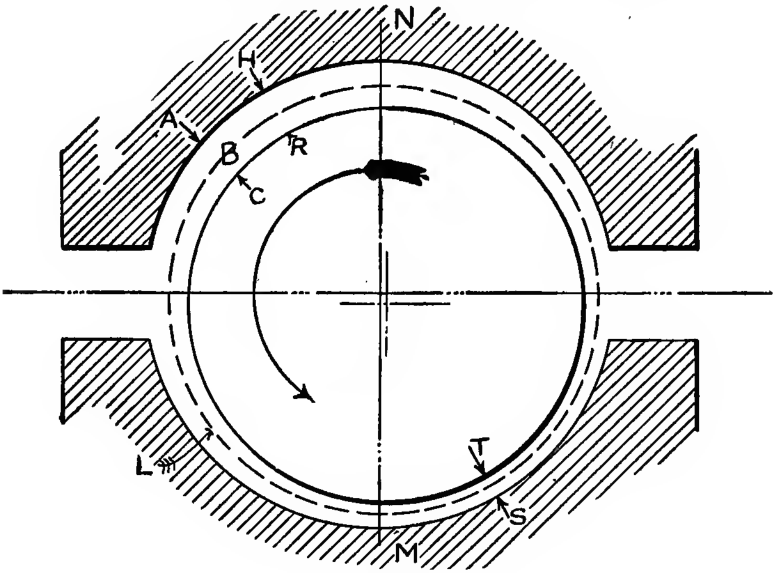


FIG. 2.—Journal and bearing.

Laws of Friction.—Professor Thurston has stated that a perfectly lubricated bearing has been found to be practically subject to the laws of fluid friction, while, as the conditions in the bearing progress towards poor lubrication, the bearing approaches the conditions to which the laws of dry sliding friction apply.

The "Sliding Layer Theory."—Referring to the journal and its bearing shown in Fig. 2, we know that to obtain the least frictional resistance, between the rotating journal and the bearing, it is necessary that the rotating part be "floated" by a film of lubricant, so that there will be no metallic contact between the surfaces.

The "*Sliding Layer Theory*" is based on the assumption that the lubricating film (*L*) is split into two or more layers, as shown at *A–B* and *B–C*. This division of the film into layers is due to the "*Adhesive*" action between the lubricant, and the metallic surfaces of the journal and bearing, which is greater than the "*Cohesive*" attraction between the particles composing the lubricant. Part of the layers, therefore, revolve relatively to the rotating journal, and the remaining layers tend to remain at rest, as is the surface of the bearing, so that a sliding movement takes place between the layers of the lubricating film. Since the frictional resistance between the oil layers is small, the frictional resistance of the bearing is reduced.

Thickness of the Lubricating Film.—It has been demonstrated by experiment, that the thickness of the lubricating film in a bearing is not uniform, but varies from an area of minimum to an area of maximum thickness, as shown in Fig. 2. This variation in the thickness of the oil film is due to the load on the journal and to the rubbing speed.

Referring to the figure again, the area *T–S* would be the area of "*Nearest Contact*" and the area *H–R* would be the area of "*Greatest Separation.*" The location of these areas has been found to shift with variations of rubbing speed and pressure of the journal.

Pressure in the Lubricating Film.—Under normal loading conditions, the "Resultant Pressure" in a bearing is in a definite direction. Of course, under varying conditions of load and speed the resultant pressure shifts, but certainly it is at all times in a definite direction.

The pressure on the oil film must, therefore, be maximum at one point and minimum at another.

The "pressure in the oil film" itself has been found, by various authorities, to be independent of the journal speed and exactly proportional to the load on the journal.

The rotation of the journal "drags" oil from the area of low pressure and into the area of high pressure. When feeding oil into a bearing, it is necessary to overcome the film pressure present at the point of entry of the oil. It is due to the neglect of this fact that many oiling systems fail in their purpose, because the pressure head of the oil feed is lower than the film pressure at the point of entry. In some cases, the pressure in the oil film may be below atmospheric pressure and the bearing may actually suck oil into the film, if the point of entry is properly selected.

Internal Friction in the Lubricating Film.—As before stated, a lubricating film is composed of several layers of oil and these layers are assumed to slip over each other at different relative speeds, with the result that friction is generated between the layers and particles, composing the film. This friction may be called " Internal Friction " and must be considered when summing up the total frictional resistance of the bearing. There is, of course, a sliding movement and resulting frictional resistance between the metallic surfaces of the bearing or journal and the lubricant, which when combined with the so-called " Internal Friction " of the lubricant, totals up to the frictional resistance developed by the bearing, *when lubricated with that particular lubricant.*

Viscosity or " Body."—The most important property possessed by an oil with regard to bearing lubrication is its *viscosity,* or *" body,"* as it is sometimes called.

The *viscosity* of an oil is a measure of the degree of its fluidity. It is that property of the oil that determines its rate of flow. The viscosity of a fluid is closely related to its internal friction, and the greater the viscosity, the higher the internal friction.

Viscosity is a measure of the combined effects of " Adhesion " and " Cohesion " possessed by a lubricant.

" Cohesion."—By Cohesion is meant that property of an oil that holds together the particles forming the oil. This property is of importance in the maintenance of the lubricating film, because the " Cohesive " properties resist the tearing apart or destruction of the film.

" Adhesion."—By " Adhesion " is meant that property of a lubricant that enables it to cling to the surfaces it is to lubricate. Adhesion aids Cohesion by resisting the tendency of the pressure in the oil film, to squeeze the lubricant from the bearing surface, and out of the bearing itself.

Surface Tension.—The property possessed by fluids and known as " Surface Tension " has been advanced by several authorities as of the greatest importance in the maintenance of the oil film.

The Surface Tension of a fluid is due to the cohesive action of the particles composing the fluid. These cohesive forces act in all directions below the surface, and, since there are no forces tending to counteract them above the surface, the unbalanced condition produces a tenseness, or drumhead-like effect, at the surface. This tension causes the surface to resist to a greater extent, any tearing apart of the particles composing it, than is offered by the particles composing the body of the fluid.

Referring to Fig. 3, M–N is a fluid surface looking along it. If the needle E is pressed against the surface, as shown, it may be depressed a small distance H without breaking through the surface. This elastic property of the surface is due to Surface Tension.

It can hardly be granted, however, that the surface tension theory proves out in practice, because actual instances have demonstrated that the **durability of the lubricating film** depends on the following conditions:

(*a*) The velocity or rubbing speed of the journal.

(*b*) The cohesive properties of the oil.

(*c*) The adhesive properties of the oil.

(*d*) The unit load or pressure on the bearing.

Surface tension of a fluid is a factor of the cohesive properties of the fluid, but in the maintenance of the lubricating film, the adhesive properties are very important, and, while high surface tension usually indicates good cohesive properties, it cannot be taken as a gauge of the value of an oil as a lubricant.

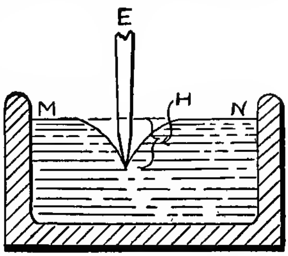


FIG. 3.—Surface tension.

The **running clearance** of the ordinary engine main bearing is only about 0.005 of an inch for a six-inch to a twelve-inch shaft. When the shaft revolves and the lubricating film is broken into several layers, it can readily be appreciated that the thickness of the individual layers must be very thin. The cohesive action within the layers is not strong enough, due to their thinness, to produce very much of an effect towards surface tension. We must, therefore, consider that it is the cohesive resistance to tear, within the body of the lubricating layers, rather than the increased elasticity of the surface of the layers, that is the deciding factor in the maintenance of the lubricating film.

"**Body.**"—A good lubricant must possess the proper proportions of the properties of cohesion and adhesion in order that it may have the greatest efficiency. An excess of either is unsatisfactory. Mercury has an excess of cohesion and very little adhesion. Water has an excess of adhesion and a low proportion of cohesion. It is obvious that neither of these fluids would be satisfactory as a lubricant.

Viscosity Requirements.—The ideal lubricant for any bearing must possess *just* enough viscosity to enable it to maintain a lubricating film

through all the conditions and requirements made upon it. It should not, however, have any excess of viscosity at normal air temperatures, or at the normal running bearing temperatures, since the internal friction of the lubricant is directly proportional to its viscosity. *Therefore, to avoid an unnecessary friction load, use an oil having as low a viscosity at stationary and at running bearing temperatures as will maintain the lubricating film.*

It is possible to increase the friction load of a bearing 25 per cent. by increasing the viscosity of the lubricant.

Lubricating oils which have high viscosities at normal temperatures, and which depend upon the frictional heat generated within the bearing to reduce their viscosities sufficiently low to meet the mechanical requirements of the bearing, are not efficient and do not meet the requirements of good lubrication.

Notes on Bearing Lubrication.—While the coefficient of friction of a lubricated bearing is dependent to some extent upon the viscosity characteristics of the oil used for lubrication, practical tests seem to indicate that viscosity, as measured through an orifice, which is the case in the usual viscosimeter, cannot be used as a basis for predetermining the probable resulting coefficient of friction that will be developed by a bearing when lubricated with that oil.

The *unit pressure* upon the bearing and the bearing speed are the determining factors which should be used in selecting a lubricant for use in any bearing.

Designers of bearings should make provision for the supplying of a definite amount of oil for each 100,000 square feet of bearing surface rubbed over.

When designing the *radiating capacity of a bearing,* a maximum temperature rise of 50° Fahr. above room temperature is a fair average for heavy, slow-speed bearings and about 75° Fahr. for light, high-speed bearings.

As before stated, *the critical or breakdown point of the oil film* is a factor dependent to some extent upon the viscosity of the oil.

For important bearings, manufacturers should always supply thermometers built into the bearings, so that any high frictional heats may be quickly noted.

CHAPTER III

HISTORICAL (PETROLEUM)

(A SHORT SKETCH OF THE DISCOVERY AND EARLY HISTORY OF PETROLEUM.)

Origin of Name.—The word Petroleum is derived from the Greek word "*Petros,*" meaning rock, and the Latin word "*Oleum,*" meaning oil, which combined mean "Rock Oil."

Origin of Petroleum.—The question of the origin of Petroleum has occupied the attention of many of the most noted scientific men for generations..

Chemists believe that Petroleum is of *inorganic origin,* or that it is the result of a miscellaneous chemical reaction between carbon and hydrogen, when they have come into contact underground.

Geologists regard Petroleum to be of *organic origin,* or, the result of a slow decomposition of organic remains (animal or vegetable), which have been stored up in rocks since they were formed. Some of the geologists claim that these organic remains are from plant life, partly water, partly marsh, and partly land species. Others maintain that this organic matter is essentially animal life much the same as found in the ocean to-day.

The organic theory seems to have the largest following, and it is possible by this theory to explain the variations in character and composition of the different crude petroleums. For instance, the light-colored crude oils from Pennsylvania are said to be of vegetable origin, while the heavy oils from the Gulf Field may originate from animal sources.

The accumulation of Petroleum deposits depends upon the presence of a coarse-grained, porous rock to act as a reservoir. The usual "reservoir rocks" are of a sandstone nature, whence comes the well-known name of "Oil Sands."

Historical.—The Egyptians made use of Bitumen in the embalming of mummies. Bitumen is of an asphalt nature. The Greeks and the Romans knew of natural earth oil long before the birth of Christ, while in other European countries there are records of Petroleum being known and used for the past three or four centuries.

The American petroleum industry dates from comparatively recent times, although the Indians knew of oil when the country was first settled.

The American Industry.—The first real step in the history of Petroleum in this country was made by the operations of the salt makers. The difficulties of bringing salt from the natural sources over the Allegheny Mountains in the early days, caused the salt men to investigate certain salt springs in their localities, which had been discovered by the wild animals of the region.

The salt men dug wells to secure more brine when the springs did not yield enough, and they were frequently troubled by a black, oily liquid, with a disagreeable odor. For years this oil was treated with indifference and used only for medicinal purposes.

In 1832 plants were built to distill "Coal Oil" from coal, to be used for illuminating purposes. The first name of this "Coal Oil" was kerosene. The demand for coal oil induced Kier, in 1852, to distill burning oils from petroleum instead of coal. This oil was sold in New York for as high as two dollars a gallon. These prices stimulated the search for Petroleum, and in 1859, Drake and his stillman, "Uncle Billy" Smith, brought in the first well ever drilled for oil in the United States, on the banks of Oil Creek, in the State of Pennsylvania.

Oil wells differ enormously in production. Some of them produce at the outset, when the flow is usually the greatest, only three or four barrels a day, while some of the big gushers produce over a hundred thousand barrels every 24 hours.

Historical Notes.—Adolph Schreiner, of Austria, made the first petroleum lamp in 1850. The first lamp to have a glass chimney was devised by an unknown Englishman and was known as the Liverpool Lamp.

The first oil speculators were Bosworth, Wells & Co., who bought crude oil in Virginia in 1843. This oil was sold for medicinal purposes in Philadelphia.

"Uncle Billy" Smith, who drilled the Drake well, was also responsible for setting fire to the first tank of oil.

In 1859, which year was responsible for the first commercial production of American Petroleum, 1873 barrels were produced and sold. They brought an average price of $20 per barrel.

In 1797 the first oil skimmed from Oil Creek to be marketed was sold at Pittsburgh, then a collection of log cabins, for $16 per gallon.

AMERICAN CRUDE PETROLEUMS

The chief fields for the production of crude petroleum in America are located in Pennsylvania, the Central United States, California, and Texas.

Pennsylvania, or Appalachian Crude.—Appalachian Crude is produced along the Appalachian Mountain Range, from Wellsville, New York, through western Pennsylvania, western West Virginia, and parts of Kentucky and Tennessee. The gravities of this crude range quite high, being from 40° to 48° Baumé (0.825 to 0.788 specific gravity). The freedom of Appalachian Crude from sulphur and other impurities makes the process of refining it simpler than for those crudes containing these impurities. Lubricating oils manufactured from this crude bring a higher price because of their excellent lubricating qualities. The cost of Appalachian crude at the wells is always higher than the prevailing prices for other crudes. Practically all cylinder stocks are manufactured from this crude, but its production is falling off considerably at the present time.

Gulf Crudes.—These crudes are produced in the States of Texas and Louisiana.

Their gravities run from 14° Baume to 25° Baume. The base of Gulf Crudes is asphalt, and the finished oils made from it are generally referred to, as Asphalt Base Oils.

During the refining process, the asphalt must be removed before arriving at the finished oils. Usually these oils are treated with sulphuric acid to remove the asphalt, and the acid is then neutralized. Lubricating oils that have been acid treated will not resist emulsification in the presence of moisture, and for those oils that are intended for turbine oils, forced-feed lubricating oils, etc., the asphalt must be removed by special methods, which may include filtration. Asphalt base oils, which have been carefully made as described, may give good results for turbine oils and for oils for circulating systems, so far as their non-emulsifying qualities are concerned.

Asphalt base lubricating oils are lower in flash-point, cold test, and gravity, than are the corresponding oils made from Northern Crudes.

The viscosities of asphalt base engine oils can be made very high without blending, but are subject to a high rate of decrease as the temperature of the oil is increased. An asphalt base engine oil may have

a viscosity twice as high as a paraffine base oil at 100° Fahr., but when the viscosities of the two oils are compared at a temperature of 150° their viscosities will have approached the same approximate value. This

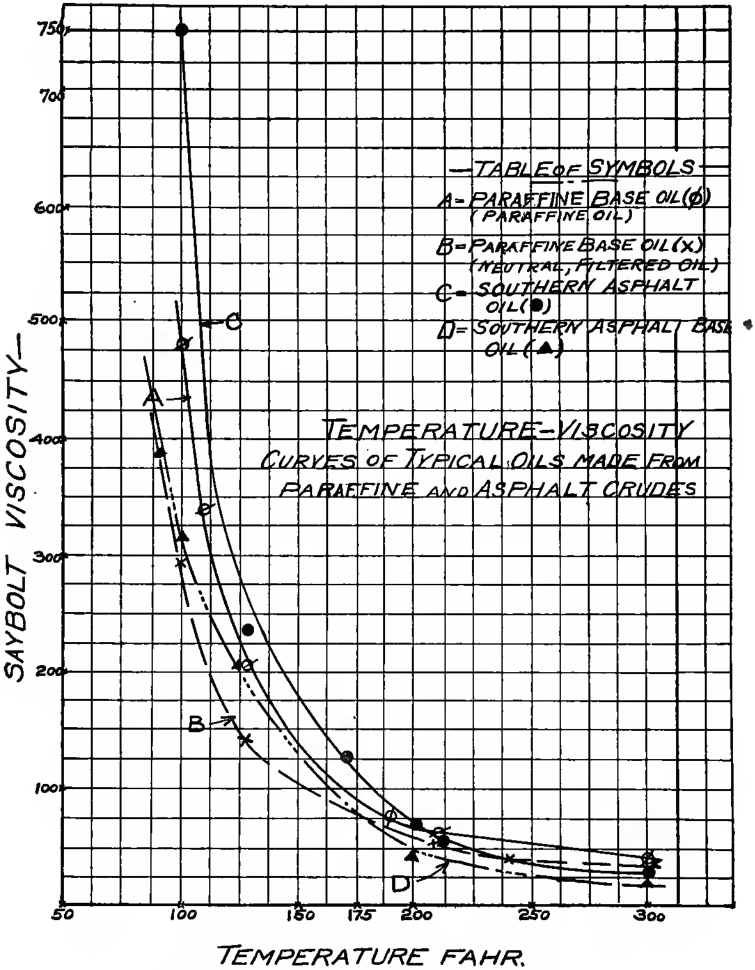


FIG. 4.—Temperature-viscosity curves of engine oils made from paraffine and asphalt base crudes.

fact makes it necessary to select an asphalt base lubricating oil from its viscosity tests at the desired working temperature of the bearing, as no dependence can be placed on the extremely high viscosities, at the standard

testing temperature for engine oils, which is 100° Fahr. The curves shown in Fig. 4 are typical viscosity-temperature curves for lubricating oils made from Gulf, Mid-Continent, and Pennsylvania crudes. They

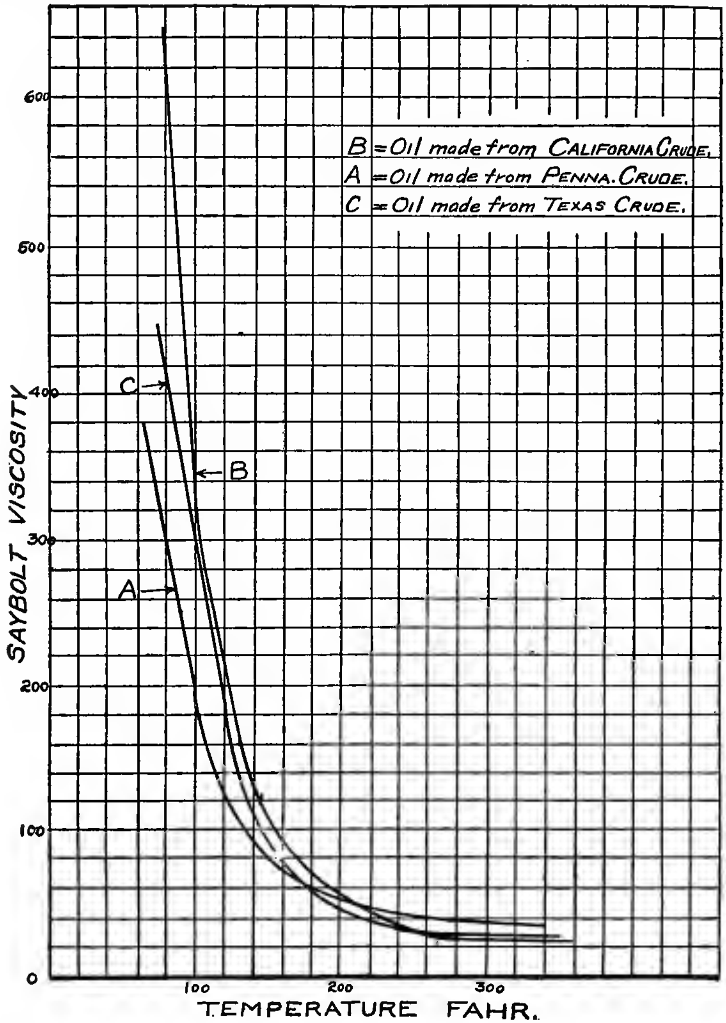


Fig. 5.—Comparison of viscosities of engine oils made from California, Appalachian, and Texas crudes.

illustrate the relative falling off of the viscosities of the oils made from the different crudes. It can be observed that at a temperature of 300° Fahr. the viscosities of all the oils are approximately the same, and this

is true for practically all petroleum engine oils. No cylinder oils are made from Gulf crudes.

Mid-Continent Crudes.—The crude produced in the fields of Kansas, Indian Territory, and Illinois is called Mid-Continent Crude. The oil occurs chiefly in pools, which vary greatly in productiveness. When first tapped the wells show a large initial production, but quickly quiet down with a great decrease in production.

The gravities of the Mid-Continent crudes range approximately from 27° to 40° Baumé.

Some cylinder oils are said to have been made from this crude. It is claimed that they can be made with the desired viscosities, but they have a very poor flash test as compared with Pennsylvania cylinder oils. Usually cylinder oils made from Mid-Continent Crude have about 35° to 45° Fahr. lower flash test than oils made from Pennsylvania Crude.

Lima-Indiana Crude.—This crude is slightly higher in gravity than the Mid-Continent crudes, ranging in gravities from 35° to 41° Baumé. This field is frequently referred to as the Trenton Rock Field, due to the large amount of Trenton limestone found there.

The oil appears in pools and is not widely distributed. It produces a large percentage of lubricating oils, but practically no cylinder stocks are made from it. There is a good deal of sulphur in the crude, and it must be carefully removed by suitable processes.

California Crude.—The California oil fields exist chiefly in the southern half of the State. This crude is heavy, its gravities ranging from 12° to

TABLE 1

SHOWING YIELDS OF FINISHED PRODUCTS*

Product	Appalachian, Per cent.	Lima-Indiana, Per cent.	Mid-Continent, Per cent.	Gulf, Per cent.
Naphthas, Gasolines, Benzines	12	11½	11	3
Illuminating oils	67	43	41	15
Lubricating oils, greases	12½	15	10	6
Fuel oil	4	..	20	30
Asphalt		..		
Acid oil		25	..	..
Gas oil		..	15	45
Paraffine wax	2	2	2	..

* NOTE.—There is a small percentage of loss during refining.

30° Baumé. The oils made from this crude have very much the same characteristics as described for the asphalt base oils.

The curves shown in Fig. 5 are typical temperature-viscosity curves, showing the comparison of the viscosities of a California and an Appalachian base lubricating oil.

Table 1 (page 32) shows the average commercial yield of finished products from the various American crudes. Of course, these amounts are very variable, and the refiner can obtain slightly greater or smaller amounts of the various products as the market requires.

FOREIGN CRUDE PETROLEUMS

Mexican Crude.—There is a considerable amount of Mexican crude now being brought into this country for home consumption. The chief use for this crude has been for fuel purposes, but lubricating oils are now being made from it that are giving fair satisfaction.

The crude contains a high amount of sulphur and salt. It has been found to contain also a commercial amount of wax.

Russian Crude.—This crude has been one of the largest competitors of American crude in production, until the Mexican Fields came in. The chief oils made from it and on the American market are those oils known as " Russian White Oils," which are largely used for medicinal purposes and for adulteration of vegetable oils. They are free from any cast or bloom which would detect their presence when used as an adulterant.

Some Figures on the Production of Petroleum.—

Year	World's production, Barrels	United States production, Barrels
1900	148,115,000	63,621,000
1905	214,398,000	134,718,000
1914	400,000,000	265,762,535

The production in Russia was 67,020,522 barrels.

Roumania	12,826,529
Galicia	5,033,350

The production of Pennsylvania Crude was as follows:

	Barrels
In the year 1914	8,170,335
In the year 1915	8,700,000 (*not complete*)

Other Crudes.—The other countries producing petroleum are: Roumania, Japan, Austria-Hungary, Dutch East Indies, British India, and, in a small way, Canada and Germany.

Notes on Petroleum Products.—It has been stated by the Bureau of Mines that the United States is producing sixty per cent. of the world's supply of petroleum. Since the discovery of oil by Colonel Drake, approximately 3,300,000,000 barrels of oil have been produced in this country up to 1916.

Our petroleum deposits are more than thirty per cent. exhausted, while our coal supply is less than one per cent. exhausted.

Petroleum products enter into the production of explosives, dyestuffs, paints, roofing, creosote oils, artificial rubber, and practically every industry, and are thus necessary to our very existence.

CHAPTER IV

PETROLEUM AND OTHER LUBRICANTS AND GREASES

(PETROLEUM AND PETROLEUM LUBRICANTS)

Petroleum Refining.—The subject of the refining of petroleum is not only interesting in itself, but a rough knowledge of the subject is essential to an understanding of the values and properties of the various petroleum lubricants.

Petroleum is a mixture of numerous hydrocarbons, each having a different boiling-point and gravity. When heat is applied to the crude and its temperature is raised, the various hydrocarbons distill or vaporize, as their respective boiling-points are reached. By condensing these vapors and collecting them in different tanks, the various products of petroleum can be separated.

General Outline of the Refining of a Typical Crude.—Each refiner has methods of his own, which he uses in handling the particular crude with which his refinery is supplied, and each crude requires special treatment to meet its individual requirements. It would not be possible to describe in detail the numerous methods of refining the different crudes, but by selecting a typical crude and outlining the processes of refining it, a general idea may be obtained of the refining of all crudes; for the principle of heating, vaporizing, condensing, and purifying is the same for all petroleum refinement.

Outline of the Refining of a Typical Crude.—The crude is usually brought to the refinery in pipe lines, which are laid a few feet under ground and which range in size from three inches to eight inches in diameter. At intervals along the line pumping stations are located, which place the oil under pressure. For moving the oil sixty miles, the pressure required in one case was a thousand (1000) pounds per square inch, and the oil issued from the pipe at a pressure of about twenty-five pounds.

A close check of the quantities pumped and received is kept at both ends, so that any leaks in the line may be quickly detected. A peculiarity of leaking oil is that it seeps upward to the surface of the ground, just opposite to water, and can thus be located easily. The crude is run into

huge storage tanks and allowed to settle. It is then pumped to the stills.

The stills are either of the old horizontal, cylindrical type, holding about 1000 to 1250 barrels per charge, or of the "Tower Type," with which many up-to-date refineries are equipped.

The Cylindrical Still.—The old-style cylindrical still is composed of a cylindrical tank, of about 45 feet in length and 14½ feet in diameter. It is erected with its long dimension horizontal, with a furnace compartment bricked in below the lower part of the shell. The upper part is left exposed to the weather.

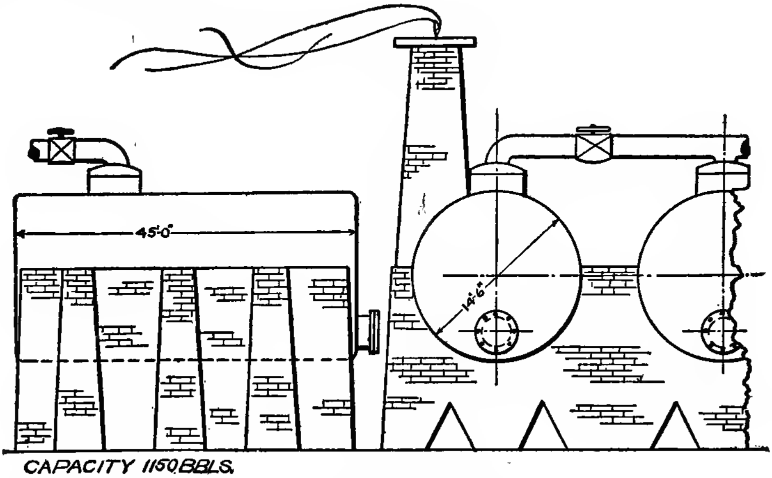


FIG. 6.—Crude stills.

There is a dome at the centre of the top, through which the vapors are allowed to escape from the still. These vapors are then passed through a cooling worm, where they are condensed. The condensed vapors in liquid form are run to the "Cut House," where, by means of taking the gravity and color tests, the various divisions and cuts are made and the oils are run to different tanks as required. Fig. 6 shows the general form of a cylindrical still.

The Tower Still.—This type of improved still is intended for the distillation of petroleum (in the form of an undistilled residue), to obtain a wide range of products in the same run; the distillation being carried, at least in part, at the high temperatures necessary to evaporate hydrocarbons with boiling-points above 600° Fahr., or above the commencement of "cracking" when the temperature is below 600° Fahr.

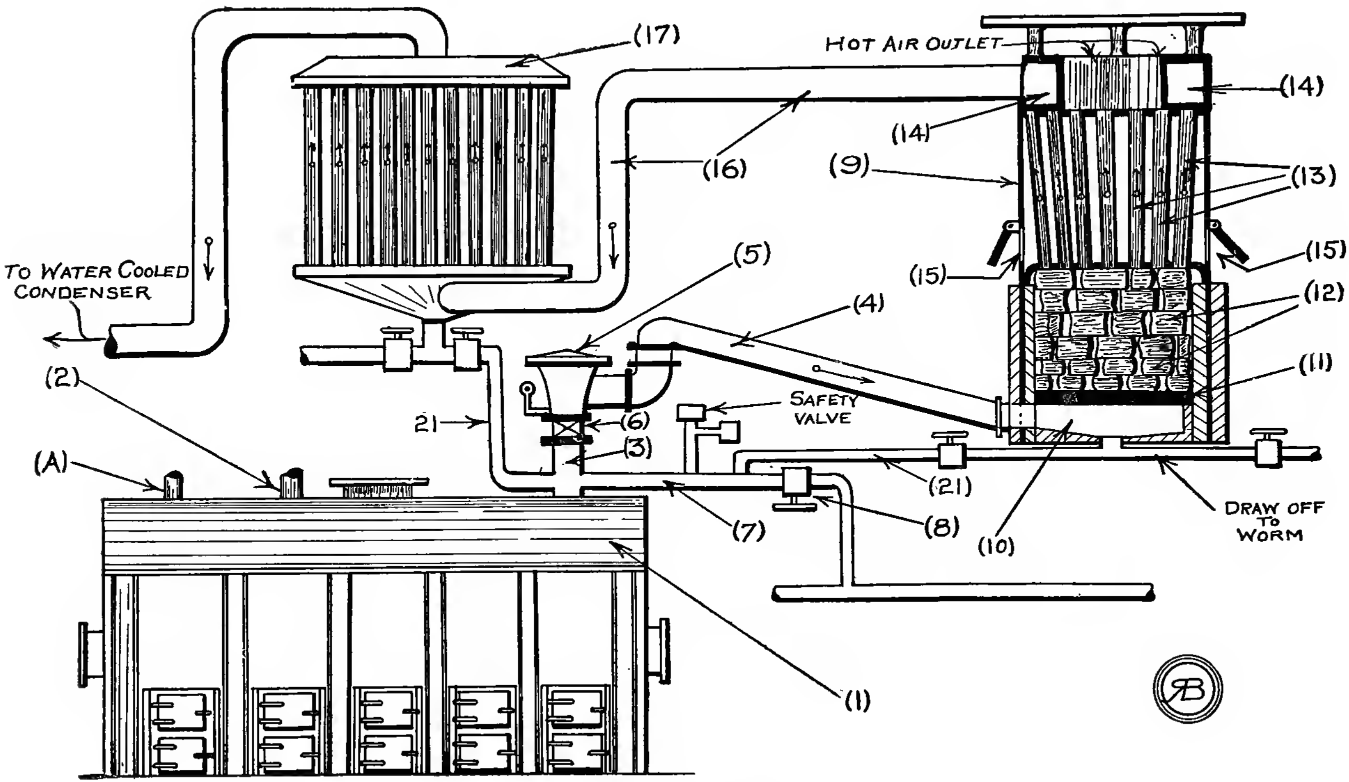


Fig. 7.—Outline of Tower Still.

This type of still makes it possible to secure the early runnings of the distillate, from a "charge of oil" in a purer state than is possible with the ordinary still.

Petroleum is distilled in "batches." With the usual type of still it is customary, before opening it for cleaning, to admit free steam to remove the remaining hydrocarbon vapors. These vapors are carried by the steam into the condensers, and remain there until the early runnings of distillate from the next charge dissolve them. This is objectionable, as these vapors are different in color, gravity, etc., from the light vapors dissolving them, and thus the early distillate is impaired.

Provision is made in the Tower Still to discharge the mingled steam and vapors through a side passage, which is designed for that purpose and which leads to a special condenser, so that they do not impair the early distillate of the succeeding run.

The so-called Tower Still Apparatus, which is covered by numerous patents, may be described as follows, by referring to Fig. 7:

A horizontal still (1) is shown, which is heated by fires beneath and is well jacketed against heat loss. A pipe (2) is supplied for filling the still with oil. The pipe (4) carries away the vapors, and is connected with an upright pipe (3), which is provided with a removable cover (5). The pipe (3) receives the pipe (4) through a side opening, and below this opening is a valve (6). There is another side opening below this valve, which receives pipe (7), equipped with a valve (8). When running, (8) is closed and (6) opened; when the still is "steamed out," (8) is opened and (6) closed.

The pipe (7) is equipped with a safety valve. Steam for "steaming out" the still is introduced through the pipe (*A*).

The vapor outlet (4) leads the distilled vapors to the partial condenser (9), entering it at the space (10), which is below the grate (11). Above the grate (11) are placed a number of cobble stones (12), which are surrounded by a nonconducting heat jacket.

Above the stones (12) is a perforated plate into which are tapped the tubes (13). These tubes, each one of which is usually equipped with a small flap valve, are enclosed in a casing or shell which fits around the header (14). This casing is provided with several air inlets at the lower part, as shown at (15). These air inlets admit more or less air as desired, the heat given off by the tubes producing a flow upward around the tubes and out at the top. The vapor outlet of condenser (9) is connected by the pipe

(16) to the inlet of the condenser (17). The two partial condensers (9) and (17) have their condensed distillate outlets connected through U traps, with valved draw-off pipes, which are led to cooling worms. "Runbacks" (21) are provided for the two condensers, and are used to return any of the condensed distillate to the still, as desired.

The still (1) usually takes about 1000 barrels to 1200 barrels for one charge, and it is heated gradually by fires until the contents of the still have become dry, or nearly so, "wax tailings" (10° B.) usually coming over last.

During the first part of the run the condensate formed in condenser 9 is returned to the still, through the runback, until the oil in distillation has attained a temperature of about 700° Fahr.

The runback is then closed and the distillate from this condenser is collected through the draw-offs.

The condensed distillate pipes from the partial condensers are equipped with cooling worms and lead into troughs, mounted on turrets, which can be revolved so as to direct the streams of distillate to various tanks as desired. The building containing the troughs is called the "Cut House." The ends of the pipes from the condensers are equipped with "Boxes" having glass fronts, so that the color of the distillate may be easily watched.

Another advantage offered by the Tower Still over the old type of cylindrical still may be pointed out as follows:

With the old type of still, the refining process was carried to a certain point, and it was then necessary to pump the residue from the crude still, at high temperatures, allow it to cool and settle, and then after several days it was pumped to the "Tar Stills," where the refinement was completed.

A "tar still" holds about 250 barrels, and it is necessary to *reheat* the charge to the point where the refinement was stopped in the cylindrical still before the residue in the "tar still" will again give off the desired vapors. This process requires a lot of extra fuel, and is, therefore, more expensive than the continuous Tower Still.

The upkeep of the "Tar Still" is high, because it requires frequent new bottoms, a very good still averaging only about 100 runs before burning out, while with the Tower Still it is possible to obtain as many as, or more than, 500 runs without exhausting the life of the bottom.

The Tower Still is very flexible, as the distillate from any part of the condensers can be run back for redistillation into the still without interfering with the other distillates.

Crude stills are run at low pressures, the safety valves being set at about 1½ pounds per square inch.

Methods of Refining.—There are two methods of refining Appalachian Crude petroleum, known as: Running to Coke or Dryness, and Running to Cylinder Stock. Nearly all Appalachian Crude is run to Cylinder Stock.

Running to Coke.*—The process of refining known as Running to Coke consists in carrying the distillation of the crude oil to dryness.

The crude is run into a still of the Tower type or plain Cylindrical type, both of which have been described. The distillation of the charge is carried on until about 50 per cent. of the oil has been distilled. These distillates are known as the "Natural Oils." When the distillates become too heavy or too dark in color to produce burning oils, the residue in the still is "Cracked."

The "Cracking Process."—In carrying out this process, the fires are slackened and the top of the still is allowed to cool rapidly. The heavy vapors now coming from the oil are at a temperature of about 650° Fahr. These vapors rise and strike against the top of the still, which is colder than their condensing temperature, and as a result they are condensed and fall back into the hot liquid below. This liquid is at a higher temperature than the normal boiling-points of the condensed liquids, and as a result the particles, falling back into this hot liquid, are immediately redistilled, resulting in an increase in the percentage of the lower boiling-point distillates, composing the naphthas and benzenes.

The "cracking temperature" of the vapors at the start is about 650° Fahr., and by the time the cracking is finished it is usually between 700° and 750° Fahr.

After the "cracking process" is completed, a "residuum" of a heavy, tarry liquid remains in the still. In the old method of refining, this residue was taken to the "Tar Stills," as previously described, but with the advent of the "Tower Still" the refinement is carried on to completion in the same still.

The "residuum" is now distilled by increasing the temperatures, and a heavy distillate is taken off at the first trap, an "intermediate distillate"

* NOTE.—This method is used chiefly for Mid-Continent crude, and other crudes.

at the second trap, and a " light distillate " at the third trap, while " tar coke " remains in the still.

The first distillate is " wax bearing," and in the last part of the run is known as " Wax Tailings." The third distillate is a high-test oil, such as " 300° Oil," while the second distillate is of an intermediate character.

" Coke."—About 5 per cent., by weight, of the crude remains in the still as " Coke." It is removed by breaking it into small pieces, running for Mid-Continent crude from 5 inches to 8 inches in thickness, and as high as 30 inches in thickness from Mexican crude.

This " Coke " is sold to manufacturers of electric light carbons and

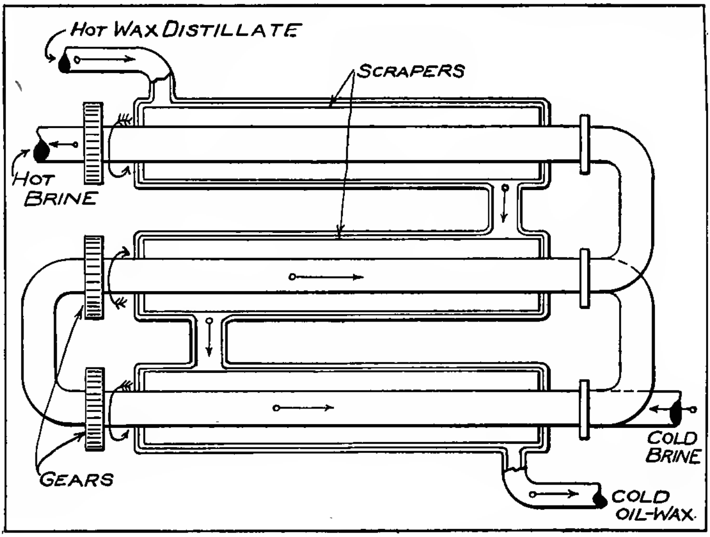


FIG. 8.—Sectional outline of chilling machine.

carbon points and to other industries requiring pure carbon. Petroleum coke contains about 99 per cent. of pure carbon.

Petroleum coke is marketed as " Chipped " and " Unchipped " Coke. When the coke is removed from the still, it has a brownish crust. This crust contains the sand and other impurities that entered the still with the crude oil. " Unchipped coke " has this crust still on it, and " Chipped coke " has been stripped of the crust.

The Wax-bearing Distillate.—This distillate is pumped to the " Chilling Machines," in which it is passed through cylinders, inside of which are inner cylinders containing cold brine.

The Chilling Machine.—An outline drawing, indicating the general construction of a " Chilling Machine," is shown in Fig. 8.

The machine consists of a series of cylinders, inside of which are other cylinders, which are of smaller diameter, thus providing an oil space between the two cylinders. The outer cylinders are stationary, and the inner cylinders are revolved by means of gear wheels, as shown. On the outside of the revolving cylinders are scrapers, which are placed there to prevent the oil flow from becoming sluggish, due to the chilling and solidifying of the wax contained in it. The hot oil from the stills is

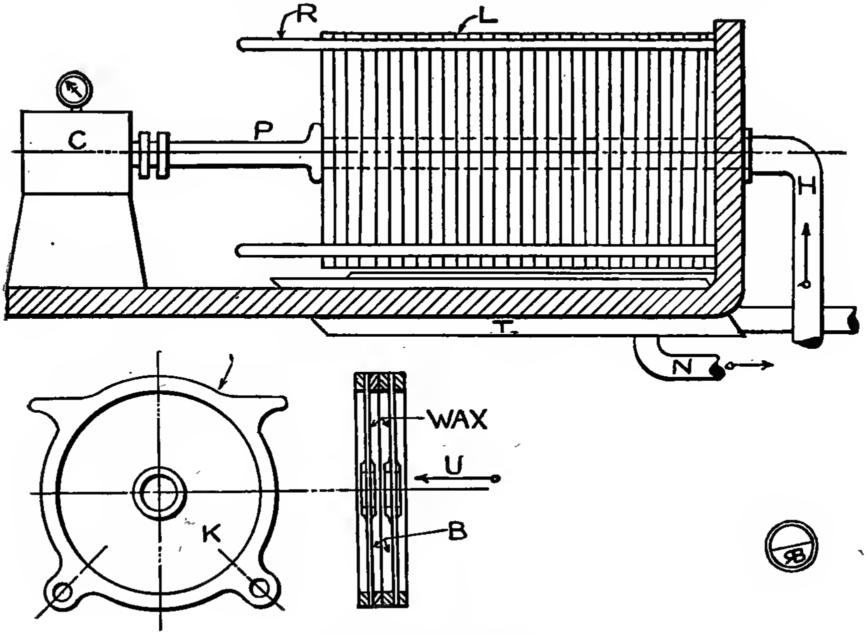


FIG. 9.—Outline of wax press.

pumped into the same end of the machine that the hot brine leaves, so that as it flows through the machine it is chilled more and more, and as it approaches the point of entry of the cold brine its temperature has reached 20° to 25° Fahr.

The Wax Press.—The cold wax distillate is pumped to the " Wax Press " after leaving the chilling machine.

Fig. 9 shows the general outline of a " Wax Press." The cold wax slop is pumped into the press through the pipe (*H*). The cylinder (*C*)

and plunger (P) are used to push the plates (L) against each other, so that the iron rings (V) around the outer edges of the plates form a tight, leakproof joint.

The plates or "Bags" (L) are shown in Fig. 9. The iron ring (V) has at its centre a sheet of canvas of a special weave. In the centre of the canvas is an opening (U). Two of these rings are pushed together to form a compartment (B).

The oil and wax enter through the pipe (H) and flow into the compartments (B). The pump pressure on the oil forces it through the canvas

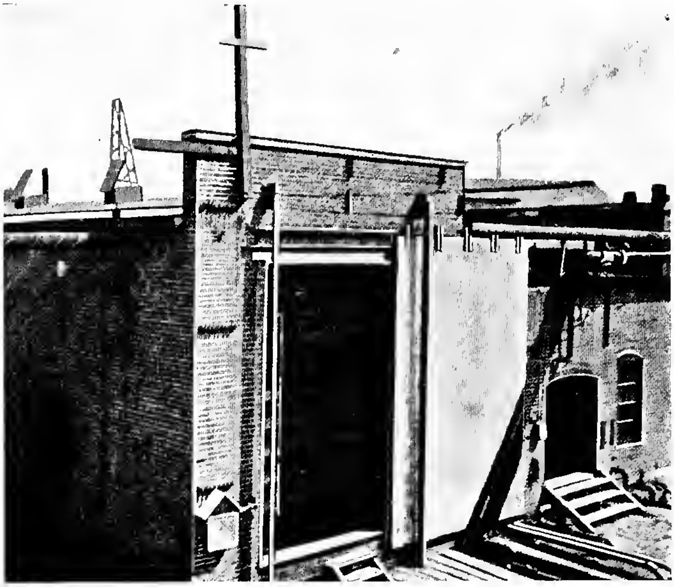


FIG. 10.—A sweater shed.

(K), as shown. The oil drips down into the trough (T), where it is collected and piped to the lubricating department. Here it is redistilled into the various bodied lubricating oils, called "Paraffine Oils."

Paraffine Wax.—The wax collected on the canvas plates is removed with chipping chisels, or "spuds," as they are called. It falls through into the trough, which is equipped with a screw conveyor that carries the wax to the "Slack Wax" tank, where it is melted and pumped to the "Sweating Sheds." Slack wax contains about 50 per cent. paraffine wax and 50 per cent. oil.

Sweating Sheds.—Referring to Fig. 10, which shows the general appearance of a "Sweater," it can be seen that it is composed of a number of pans which are held on racks in the shed. Each pan is equipped with a coil of pipe run near the bottom. The oil and melted wax is run into the pans and then chilled by water running through the pipes until it is solid. The temperature of the solid mass is next slowly raised, and under these conditions the oil is gradually sweated from the wax and flows away, carrying with it most of the coloring matter contained in the slack wax.

Paraffine Scale Wax.—If the sweating process is stopped when the wax contains a low percentage of oil, the wax is called "Paraffine Scale."

Sweated Wax.—A wax sweated free from oil is called "Sweated Wax." By resweating, different grades of wax may be obtained, ranging in melting-points from 115° Fahr. to 136° Fahr.

Decolorizing.—The yellow sweated wax may be melted and filtered through bone dust or fuller's earth, and the product is called "Refined Wax," and should be colorless, odorless, and tasteless. When the filtering medium becomes exhausted, the wax becomes more and more colored and is called "Semi-refined Wax."

Paraffine Oil.—The paraffine oils from the presses are treated, redistilled, and manipulated to produce the various oils, ranging from the light spindle oils to the heavy machine oils. Paraffine oils are always obtained from oil that has been cracked. The oils may be treated with sulphuric acid to throw down the unstable compounds, free carbon, etc., washed with water, neutralized with an alkali, and the whole again washed and separated. The remaining oil is then blown with air to remove any traces of water that may be present.

Sometimes the oil fraction is partially decolorized by sulphuric acid treatment, and is then filtered to complete the decolorization necessary to produce marketable standards. These oils may be called "Filtered Oils." Oils produced by these processes are brilliant to the eye. When oils are refined by these processes they contain hydrocarbon sodium salts ("Sulpho"). Oils containing these sulphuric or sulphonic compounds will form a curdled mass when mixed with water, to a more or less extent, depending upon the amount of the "sulpho" compounds present.

Paraffine Lubricating Oils.—These oils make very satisfactory lubricants and have good wearing qualities. They should never be used in

the crank cases of " splash-fed " steam engines, in steam turbines, or any machinery in which the lubricant is likely to come into contact with water. The gravities of paraffine oils usually run between 21° and 26° Baumé. Chart I shows the products obtained when a Pennsylvania Crude is " refined to dryness."

RUNNING TO DRYNESS OR COKE. (PENNA. CRUDE)

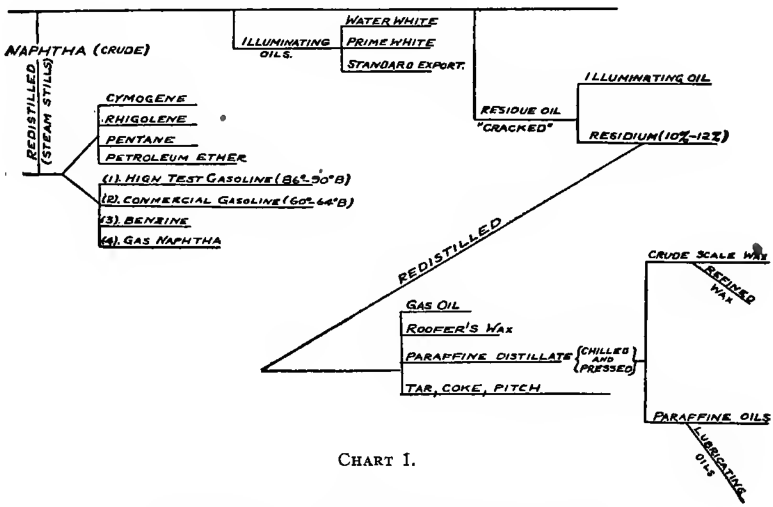


CHART I.

RUNNING TO CYLINDER STOCK

In the " Running to Cylinder Stock " method of refining, the oil is not allowed to crack. It is run into " Steam Stills," which are heated both by fire underneath and by steam within. The steam is brought into the still at the bottom, through perforated coils, and is allowed to bubble up through the oil.

The steam is introduced into the still to preserve the color of the lubricating oils and to keep the temperatures down. It displaces the oil vapors before they have had time to be cracked.

This method of refining is about the same as that described under the " Running to Dryness " process, up to the point where " cracking " would have occurred. In the " Running to Cylinder Stock " method, the refinement is carried on until the distillate becomes too heavy for illuminating oils. The fraction remaining in the still is called " Wax Slop," and the residue obtained is much larger than that obtained in the " Running to Dryness " method.

Gas Oil.—Sometimes the "wax slop" is redistilled and a heavy illuminating distillate is obtained. What is known as "gas oil" may be obtained at this point.

300° or Mineral Seal Oil.—An oil known as 300° or "mineral seal" burning oil may be obtained at this point in the distillation. This oil is used in signal lamps on ships and for lighting purposes by the railroads. Its high fire test makes it safer than the ordinary burning oil.

Cylinder Stocks.—The residue remaining in the still after the "wax bearing" distillate has been taken off is called cylinder stock, and is a heavy, viscous lubricating oil, used principally for steam engine cylinder lubrication. This stock is filtered and reduced as desired, to produce the various oils as demanded by the trade.

Pressed Distillate.—The "wax-bearing distillate" is chilled in the chilling machines and then pressed. The pressing yields wax and "pressed oil." The pressed oil differs from the oils obtained from the pressing of the wax-bearing distillate obtained in the "Running to Dryness" method.

Neutral Oils.—The term "neutral oils" is given by the trade to those oils obtained from the "pressed oil." There are "treated neutrals" and "filtered neutrals." Usually neutral oils are filtered, however, to preserve their qualities. "Treated neutrals" will run a little lower in gravity than "filtered neutrals." The gravities of "neutral oils" are higher than those of "paraffine oils."

"Neutral oils" are sometimes referred to by the trade as "Viscous" and "Non-viscous Neutrals." Generally speaking, neutral oils above 135 Vis. @ 100° Fahr. are called Viscous Neutrals, and those below 135 Vis. @ 100° Fahr. are called "Non-viscous Neutrals."

Neutral oils are sometimes "Debloomed" to remove the "cast" or "bloom." "Deblooming" is the process of exposing the oil in shallow tanks to the weather. This process bleaches the oils and makes them hold their color. The "cast" or "bloom" of an oil can be easily detected by placing a drop on a black surface and viewing it by reflected light. The cast will be detected by a bluish color. Neutral oils are sometimes used to adulterate cotton-seed oil and other outside oils, and a cast or bloom would reveal their presence to an experienced observer.

The most important difference between the characteristics of "neutral" and "paraffine" oils is their behavior in the presence of moisture.

Neutral oils will not emulsify when in contact with water, as will paraffine oils, and, while there are some paraffine oils on the market which have very good non-emulsifying qualities, it is always dangerous to use them in any place where they are liable to be exposed to water. Neutral oils should be used for crank-case lubrication of steam engines, in circulating systems, for turbine lubricating systems, etc.

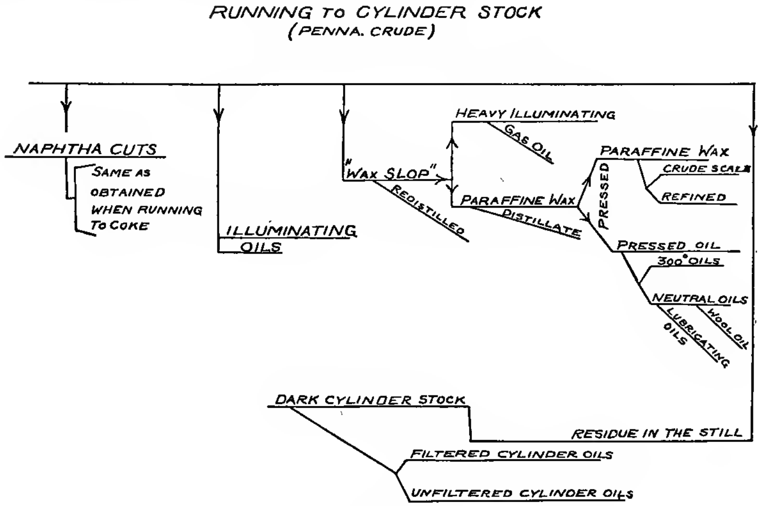


CHART II.

Chart II shows the products obtained by refining a Pennsylvania Crude by the " Running to Cylinder Stock " Method.

Black Oils.—Black oils are marketed as " Summer " and " Winter " black oils. The " Summer " black oils have a higher viscosity than " Winter " black oils, and the cold test of the winter oil is lower by about 15° to 20° Fahr. than that of the summer oil.

The standard method of making black oils is to thin out petroleum residuum with distilled oils from the intermediate cut.

" Summer " black oils have less of the distilled oil in their makeup than " Winter " black oils have.

There are numerous ways of making black oils, but the above method may be considered as a typical one.

Pressure Stills.—These stills are used to redistill the lighter portions of the pressed oils and heavy distillates at a pressure of about 75 pounds, so that the oil may be broken down and the naphthas recovered.

Other Crudes.—The methods of refining Lima, California, and Texas crudes are similar in principle to the methods described above, but various individual conditions, such as an excess of asphalt, sulphur, or salt, require detailed consideration. Of course, those oils that do not contain any commercial amount of paraffine wax are not passed through the chilling and pressing processes. A typical paraffine base crude contains about 2 per cent. paraffine wax.

CHEMICAL STRUCTURES OF VARIOUS CRUDE PETROLEUMS

The chemical structure of the compounds found in crude oils from various bases may be briefly outlined as follows:—

Paraffine Base Oils belong to the methane series, which has the characteristic formula: $C_nH_{2n} +_2$.

Asphalt Base Oils belong to the series of hydrocarbons containing more carbon to the molecule (unsaturated). The characteristic formula is: C_nH_{2n} equals the "*Olefins.*"

C_nH_{2n-2} equals the "Acetylenes."

Russian Oils are made up chiefly of the naphthene series of hydrocarbons, whose formula is: $C_nH_{2n-6} + H_6$.

It may be seen from the above that all lubricating oils are composed of various chemical compounds of the element carbon and the element hydrogen, hence there are no so-called "non-carbon" oils.

ANIMAL, FISH AND VEGETABLE OILS

Whale Oil.—This oil is obtained from the "blubber" of the whale by melting the "blubber" and thus removing the oil from the tissues. It is brownish yellow and has a bad smell.

Lard Oil.—This oil is obtained from the fats of the hog. It saponifies quickly and has a cold test of about 32° Fahr.

Lard oil should be made from fresh lard and should never be made from lard of "mast" or distillery-fed hogs, as it will not give good results in service. Oil made from old lard should not be used, as it will give trouble from gumming. There are several grades of lard oil on the market, but only Extra No. 1 lard oil should be used, to compound with mineral lubricating oils. Low-grade lard oils contain a high percentage of fatty acid.

Neat's-foot Oil.—This oil is obtained by boiling the feet of cattle and skimming off the oil that rises to the surface of the water. Its color is very light straw to dark straw. It has no odor when fresh. Its cold test is about 32°.

Tallow Oil.—This oil is manufactured from the tallow of beeves by pressure. It has many similarities to neat's-foot oil. "Stearine" is obtained from it by slow cooling and straining.

Sperm Oil.—Sperm oil is obtained from the head of the whale. It is slightly different from whale oil, in that it is not of so high a fatty nature, and is not as easily saponified as whale oil.

VEGETABLE OILS

Drying and Non-drying Oils.—The two classes of vegetable oils are drying and non-drying oils. Only non-drying oils should be used for lubricating purposes. A fixed or non-drying oil is not subject to oxidation and gumming as drying oils are. The fixed oils used in compounding with mineral oils are "rapeseed," "Colza," and "cotton-seed" oils.

Cotton-seed Oil.—This oil is produced in numerous grades from the seed of the cotton plant. These seeds are removed from the "boll" by the "ginning" process and are then crushed and the oil expressed. Its color is usually deep yellow to dark reddish yellow. Cotton-seed oil is largely used to compound with petroleum oils, to produce miner's lamp oil and certain lubricating products. It is often used to adulterate lard oil.

Rapeseed Oil.*—This oil is expressed from the rape seed. The crude is then subjected to "blowing." This is a process of oxidation (limited), which consists in forcing a current of air through the heated oil. The "blowing" process increases the density and the viscosity of the oil and is continued until the desired result is obtained.

Castor Oil.—This oil is sometimes used as a compound for lubricating oil. It is a non-drying oil, but will thicken on long standing, and when used as a lubricant quickly thins out in service.

Rosin Oil.—The destructive distillation of common rosin produces "rosin oil." It is not suitable for use as a lubricant, though often used as a compound by manufacturers of cheap oils and greases.

Gumming.—Drying or gumming is usually caused by the gradual

* NOTE.—In some localities the name "Colza Oil" is given to the oil made from the original plant and the name of Rapeseed Oil is given to the oil obtained from a developed variety of the plant, called "Rapo."

conversion of vegetable oils into rosin. It goes on rapidly with drying oils and slowly with fixed oils.

Table 2 tabulates the properties of the various animal and vegetable oils used as lubricants.

TABLE 2

PROPERTIES OF ANIMAL AND VEGETABLE OILS

Kind of oil	Gravity Baumé Degrees	Specific gravity	Natural color	Fixed drying	Cold test Degrees	Odor
Water	10	1.000	—	—	—	—
Lard Oil	23	.915	Nearly colorless	Animal	32–50	Lard
Castor Oil	15	.965	Colorless	Drying	5	Bad
Colza Oil	23	.915	Limpid yellowish	Fixed	20	—
Rapeseed Oil	23	.915	Clear yellowish	Fixed	20	Bad
Tallow (beef)	—	—	—	—	100	—
Cotton-seed Oil	21	.927	Yellowish-brownish	Fixed	30	—
Linseed (boiled)	19	.939	Yellow, gold, brown	Drying	—	Strong
Linseed (raw)	21	.927	Yellow, gold, brown	Drying	—	—
Menhaden (light)	20	.933	—	Fish	—	—
Menhaden (dark)	21	.927	—	Fish	—	—
Neat's-foot Oil	23	.915	Yellowish	Animal	—	None
Olive Oil	22	.921	Yellowish-greenish	Fixed	—	Slight
Sperm Oil	29	.8805	Limpid orange yellow	Animal	—	Fishy

Saponification.—The Kottstorfer value is expressed in the number of milligrams of potassium hydroxide (KOH), that is required to saponify one gram of the fat. While the chemical reactions and theory are of no practical value to the oil engineer, the relative saponification values of the various oils and fats are of interest in the numerous discussions arising, relative to the values of the different oils as materials for compounding purposes. The following values were given in a list prepared by Mr. C. A. R. Wright in London in 1894. (Fixed oils, fats, butters and waxes.)

TABLE 3

SAPONIFICATION VALUES OF VARIOUS OILS

Beeswax (Yellow)	95/100
Beeswax (White)	....
Castor Oil	201/203
Cotton-seed Oil	194/195
Linseed Oil	190/192
Lard Oil	195/196
Menhaden Oil	192/
Neat's-foot Oil	191/193
Olive Oil	191/193
Sperm Oil	134/
Wool Grease	190/191
Whale Oil	169/170

Viscosity of Castor Oil.—An idea of the effect of temperature rise, on the viscosity of chemically pure castor oil, may be obtained from the following figures (obtained from an average sample) :—

100°	Fahr.	....	Vis.	Say.	1200	seconds
125°	"	....	"	"	600	"
150°	"	....	"	"	300	"
175°	"	....	"	"	175	"
200°	"	....	"	"	110	"
250°	"	....	"	"	60	"
300°	"	....	"	"	40	"

GRAPHITE

Graphite.—Graphite exists in two forms: Flake and Amorphous. Crystalline graphite or Flake graphite is dense and compact and is not easily reduced by crushing between the fingers, so that the individual particles maintain their size. "Amorphous" graphite, under pressure, continues to be reduced in size until the particles are no longer evident to the touch. Flake graphite is the better lubricant, because it has good wearing qualities and adheres to metallic surfaces with which it comes into contact. Graphite is not affected by heat. The value of flake graphite as a lubricant lies in its property of filling any irregularities that exist in a bearing surface, thus reducing the roughness of the surface and producing a better surface for lubrication with oil or grease.

Graphite is of value as a lubricant for steam engine cylinders, provided it is used in great moderation and not fed in excess. The entire value of graphite as a lubricant is lost, if an excessive amount is used.

When the valve seats and cylinder walls of an engine are badly cut or scored, the addition of a little graphite, (several teaspoonfuls), mixed with the cylinder oil, will greatly aid in smoothing up the bearing surfaces.

For steam engine cylinders using superheated steam, flake graphite is of great value. It aids in filling up the irregularities of the cylinder wall surfaces, so that the cylinder oil, which is greatly reduced in viscosity by the high temperatures found in these cylinders, will have the best possible surface conditions to work on.

In order to obtain a clear idea of the value of graphite as a lubricant, the engineer must appreciate the fact that in order to be efficient, graphite must identify itself with the metallic surfaces to be lubricated. Its function is to fill up the pores and depressions in the surfaces, giving them a smooth polished finish. Lubricating oil must then be introduced be-

tween the rubbing surfaces so as to produce a film, which will be more efficient in its results because of the reduced frictional resistance to be overcome, due to the graphited surfaces.

The specific gravity of graphite is 1.81, and, therefore, is greater than that of oil, and for this reason it will settle out of oil on standing. It is not possible to permanently suspend graphite in oil. A mixture of oil and graphite should never be put in an oil cup or sight-feed lubricator, as the graphite will soon clog the feed passages.

For engine bearings a heaping teaspoonful of graphite to a pint of oil is sufficient.

About 4 per cent. by weight of graphite is the average good practice when mixed with oils and greases, and gives good results when applied at reasonably long intervals.

Graphite should never be used on bearings supplied with forced or flooded continuous lubrication.

LUBRICATING GREASES

Petroleum cup greases consist of lime soaps, mineral oils, and resin oils. Soap gives the grease melting-point and body.

Cup Greases.—The manufacture of cup greases is generally as follows:

(*a*) Saponification of fatty oil with calcium hydroxide in the presence of water.

(*b*) On completion of the saponification, hydrocarbon oil (petroleum) is added to the soap formed and blended into a homogeneous mixture.

In making a so-called "Hot-set" grease, fat is boiled with the caustic soda and a little lime to change its appearance, then the mixture is dried and mineral oil is worked in.

In making a so-called "Cold-set" grease, lime, a little water, and resin oil are combined with a neutral mineral oil.

Free Tallow.—Most greases contain about 3 per cent. free tallow.

Total Fat.—The total fat in good engine grease runs from about 15 to 26 per cent.

Fillers.—Many unscrupulous grease manufacturers weight their greases with a "filler," to give it body. These fillers may consist of wax, resin, talc, or some other substance equally worthless as a lubricant.

Animal Greases.—Some greases on the market are made from animal

oils. These greases become rancid when warmed and are injurious to the bearings in which they are used. Often these greases are scented with some oil, such as oil of citronella, to hide their identity.

Specifications for Cup Greases.—Cup grease should be a homogeneous mixture and should be composed of not less than 80 per cent. mineral oil of 24° Baumé to 28° Baumé gravity. In addition, it should contain only odorless lime soap made from pure animal fats, with just enough lime for saponification. The "ash content" should never be more than 2.75 per cent. The grease should not contain any grit, resin, or fatty acids. On heating for an hour at 230° Fahr., not more than 3 per cent. of its weight should be lost.

Fibre Grease.—This grease is usually made by saponifying a fatty oil with sodium or potassium hydroxide and a little water. On completion of the saponification, the water is boiled out and mineral oil is added.

By varying the quantity of the constituents used, light, medium, and hard greases are made. Fibre greases of good quality will return to their former general consistency, after they have been heated to fluidity and allowed to cool. This grease is of a distinctly fibrous nature and when pulled apart the small fibres may be seen sticking out at the edges.

Semi-fluid Oil and Greases.—By varying the amounts of saponified fatty oil and combining less of it with mineral oil, the semi-fluid oils and greases are made. The general process is the same as described for cup greases. These products are used as lubricants for worm gearing and other mechanism requiring a lubricant, midway in stiffness between a cup grease and the heaviest lubricating oils.

Gear Compounds.—Cheap inferior grades of gear compounds are made by mixing paraffine wax with a heavy mineral oil. Paraffine wax is not a lubricant. Good gear compounds are usually made by blending a mineral oil with a fibre grease.

Graphite Greases.—For certain cases where bearings are exposed to dampness, and where it is necessary to use a grease instead of an oil, graphite grease will give the best results. The addition of graphite tends to prevent the grease being washed from the bearing. A grease of this nature is often used on the exposed bearings of street railway cars.

Specifications for Graphite Grease.—Graphite grease should consist of about one part of amorphous graphite pigment and two parts of a homogeneous mixture of mineral grease and a metallic soap pigment.

It should not show more than 15 per cent. ash, and should not contain any uncombined resin or resinous oils.

Steam Cylinder Grease.—Grease may be used as a steam cylinder lubricant. The grease is fed to the cylinder by means of a specially designed lubricator, which first melts the grease and then feeds it into the steam line, where it is atomized by the steam.

The usual cylinder grease on the market is composed of about 85 per cent. mineral oil and 15 per cent. tallow, the mineral oil component consisting of about 66 per cent. of a filtered cylinder stock and 33 per cent. petroleum grease.

There is no possible advantage in using a cylinder grease, and if its cost is compared with the ordinary, or even the highest, priced cylinder oil, it will be found that the grease is a very expensive proposition (figuring 7½ pounds of grease to the gallon of cylinder oil).

There are numerous claims made for the lubricators, loaned by the manufacturers of these greases, but none of these claims are borne out in practical use that could not be obtained with a well-regulated cylinder sight-feed lubricator.

Pinion Greases.—Pinion greases are usually made from residuum from the stills. It can be produced in various consistencies, from that of heavy cylinder oil to a grease so stiff that it must be warmed to cause it to flow. These greases have a high adhesive power and will stick to an exposed bearing under the most adverse conditions. The thinner bodied greases are frequently used as wire cable coatings. Usually a little pine tar is mixed with the grease during manufacture. Some pinion greases are entirely made from pine tar, but these greases do not possess the adhesive or lubricating qualities of the residuum grease.

Petroleum Grease.—Petroleum grease is a sort of amorphous wax. It is obtained as follows: When refining to cylinder stock, the residue in the still, which is a cylinder stock, is mixed with naphtha. This mixture is then allowed to settle, while being kept at a low temperature. The mixture separates into two parts, the lower being the petroleum grease, and the upper part is drawn off. This upper part is then heated to drive off the naphtha, which can be used again, and the remaining residue is a low cold test cylinder stock.

The petroleum grease may be filtered to produce the different colored petrolatums. With some crudes, it is possible to obtain the petrolatum

stock by straight refinement; that is, it remains as a residue in the still, after the lighter parts of the crude have been distilled off. These crudes are very few, however, and come from certain sections of Pennsylvania.

Tallow Greases.—The so-called "tallow greases" are usually made with some hard animal fat, in combination with a small amount of mineral oil. The mixture is solidified by the use of soap. Its melting-points are usually between 50° and 75° lower than the melting-point of the usual petroleum "cup grease."

Grease Lubrication.—Undoubtedly, greases are excellent lubricants when properly used. They have, however, a very narrow range of service, and they should not be called upon to perform the functions of lubrication under conditions to which they are not suited.

The use of any solidified lubricant places a drag or friction load on the machine it is used upon. The chief advantage of grease as a lubricant lies in its cleanliness and in its property to "stay put." In bearings revolving at a slow speed, where it would be difficult to maintain a film of lubricant, grease may be used to advantage.

For crank-pin bearings of high-speed engines, grease will give satisfactory results. In the case of the slow-speed bearings mentioned above, grease is an efficient lubricant, because, due to its adhesiveness, it will maintain a layer of lubricant when the machine is at rest, and thus reduce the starting friction when the machine is placed in operation.

Stearic Acid.—Stearic acid, which may occur in a free state in inferior grease, attacks iron, steel, and all their alloys. For this reason great care must be used in selecting a grease.

CHAPTER V

LUBRICATING OIL AND GREASE TESTS

In the past, physical tests were used as a deciding factor in the selection or rejection of lubricating oils, and an attempt was made to arbitrarily designate certain definite physical and chemical properties that the oils were expected to possess, to satisfy a given mechanical requirement.

It is unfortunate that lubricating oils lend themselves so readily to a number of scientific tests, because, due to this fact, these tests have become the common property, to a very considerable extent, of operating engineers, oil salesmen, purchasing agents, and others who are not equipped with sufficient knowledge of the refinement of oil to appreciate what the tests really signify. The result has been that in the present day, when lubricating oils are made from many different crudes, each crude producing oils having individual characteristics, the trade has become so confused and the selection of a lubricating oil for any purpose so difficult, that an economical and efficient choice is largely a matter of luck.

PHYSICAL TESTS

The physical tests generally met with by the average person engaged in the sale, application, and purchasing of lubricating oils are as follows: Viscosity, Cold Test, Gravity, Flash-point, Fire-point, Evaporation Test, Acidity Test, Test for Tarry Residues, Test for Compound Oils, Gumming Test, and De-emulsibility Tests.

Specific Gravity.—The specific gravity or density of an oil is the ratio, by weight, of a given volume of the oil as compared with the weight of the same volume of water at 60° Fahr.

The specific gravity of a fluid is measured with a hydrometer.

Hydrometer.—A hydrometer is usually made of glass and consists of three parts (see Fig. 11). *A* is the upper part or graduated scale on which the readings are taken, *B* is the bulb or enlargement of the tube containing air, *C* is a small bulb at the bottom of the tube, containing shot or mercury to weight the tube. The upper scale is graduated to read directly in specific gravity, or it is divided into an arbitrary scale, called **Baumé**

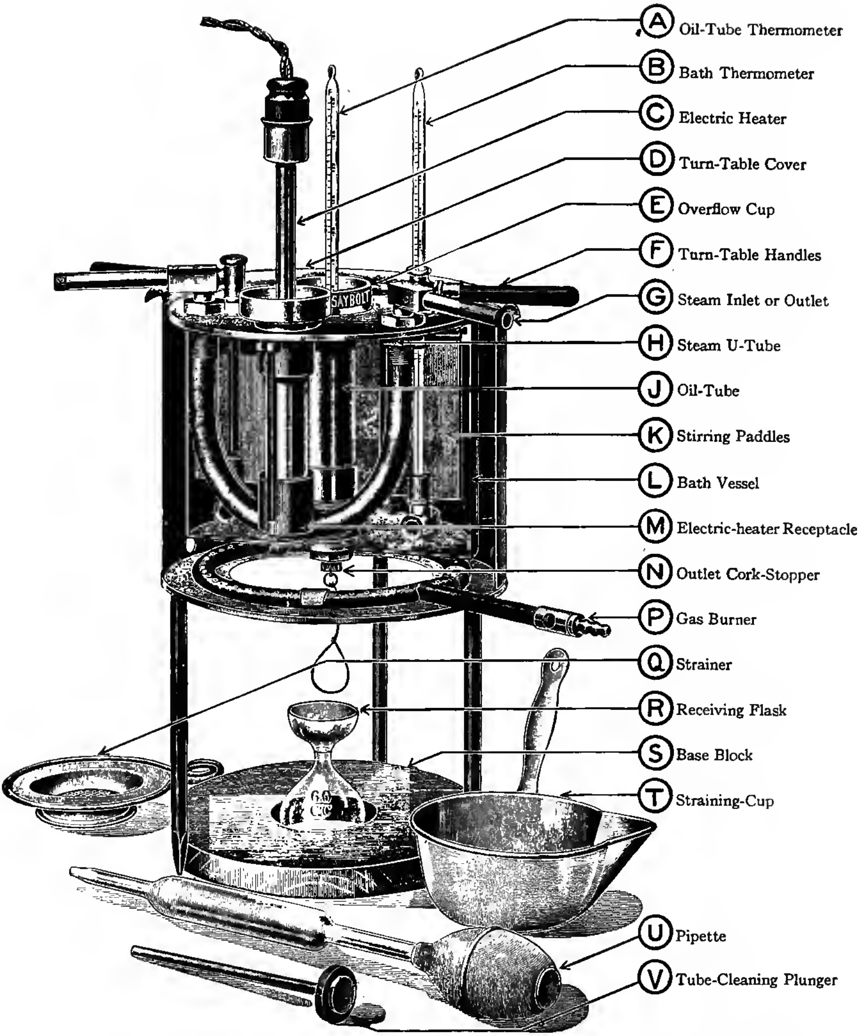


FIG. 12 A.—Saybolt Standard Universal Viscosimeter. (View shows one-half of stand jacket and bath vessel, cut away to show inside parts.)

Gravity. The oil trade generally use the Baumé hydrometer for all gravities.

The standard temperature at which gravity should be referred to is 60° Fahr. Increase in temperature decreases the specific gravity readings, and suitable correction must be made in the readings obtained by the hydrometer to allow for the number of degrees the oil temperature exceeds or is below 60° Fahr.

Baumé Hydrometer.—In the oil trade it is customary to use the Baumé gravity scale. With this scale the gravity of water is 10, at the standard temperature of 60° Fahr. The lighter the oil is in body, the higher the Baumé reading. For instance:

Water	10
Cylinder Oil	24–27
Heavy Engine Oil	18.5–28
Light Engine Oil	21.5–31

Baumé Temperature Correction.—When using the Baumé hydrometer, it is customary to deduct 1 from the hydrometer reading, for every 10 degrees Fahrenheit that the temperature of the oil is above 60° Fahr., and to add 1 for every 10 degrees that the temperature is below 60° Fahr. As an example, if the hydrometer reads a gravity of 30° at 70° Fahr., the corrected reading would be 29°. This correction gives only an approximate result and is suitable for field work only. For accurate corrections, refer to Table 4, which gives the exact gravities at various temperatures.

Comparison of Specific and Baumé Gravities.—The relation of specific gravity readings to those of the Baumé scale is given by the following formula:

$$\text{Specific gravity} = \frac{140}{130 \text{ plus Baumé reading.}}$$

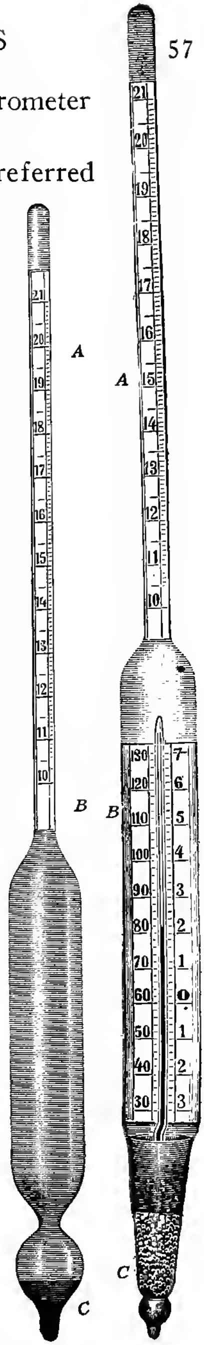


FIG. 11.—Hydrometers with Baumé scales.

TABLE 4

BAUMÉ GRAVITY TEMPERATURE CORRECTION

Baumé gravity	45° Fahr.	50° Fahr.	55° Fahr.	60° Fahr.	65° Fahr.	70° Fahr.	75° Fahr.
20	20.8	20.6	20.3	20.0	19.7	19.4	19.1
21	21.8	21.5	21.3	21.0	20.7	20.4	20.1
22	22.8	22.5	22.3	22.0	21.7	21.4	21.1
23	23.9	23.6	23.3	23.0	22.7	22.4	22.1
24	24.9	24.6	24.3	24.0	22.7	23.4	23.1
25	25.9	25.6	25.3	25.0	24.7	24.3	24.0
26	26.9	26.6	26.3	26.0	25.7	25.3	25.0
27	28.0	27.6	27.3	27.0	26.7	26.3	26.0
28	29.0	28.6	28.3	28.0	27.7	27.3	27.0
29	30.0	29.7	29.3	29.0	28.7	28.3	28.0
30	31.0	30.7	30.3	30.0	29.7	29.3	29.0
31	32.1	31.7	31.3	31.0	30.6	30.3	29.9
32	33.1	32.7	32.4	32.0	31.6	31.3	30.9
33	34.1	33.7	33.4	33.0	32.6	32.3	31.9
34	35.1	34.8	34.4	34.0	33.6	33.3	32.9
35	36.2	35.8	35.4	35.0	34.6	34.3	33.9
36	37.2	36.8	36.4	36.0	35.6	35.2	34.9
37	38.2	37.8	37.4	37.0	36.6	36.2	35.8
38	39.2	38.8	38.4	38.0	37.6	37.2	36.8

Use of Hydrometer.—The oil to be tested is put into a tall jar and the hydrometer inserted carefully, so that the force of its plunge does not cause the instrument to dip too far into the oil, allowing it to rebound and carry back some of the oil adhering to the stem, which would affect the reading by placing this additional weight upon the hydrometer. If the oil is transparent, note the lower meniscus, and if not transparent, allow for capillary attraction and note the point where the oil surface would have struck the stem of the hydrometer.

The only practical value of the gravity test is the determination of the source of the crude from which the lubricating oil was made. Lubricants made from asphaltic base crudes, such as Texas and California oils, will range from 7 to 10 degrees Baumé lower than oils made from paraffine base crudes.

Gravity has no effect upon the lubricating merits of an oil, and, as a matter of fact, ordinary machine oils will show a wide range of gravities, even though coming from the same crudes.

Gravity serves, to some extent, in checking current deliveries of a certain brand of oil, by maintaining the uniformity of the deliveries.

The refiner will not usually guarantee the exact gravity of any brand of lubricating oil, because current deliveries coming from different batches

of the same crude and with the same method of distilling will show some variation. The gravity of an established brand of oil is usually fixed between definite limits. Mineral oil is not a fixed chemical body of unchangeable character, and if the buyer insists on an exact and definite gravity, the oil is simply blended and doctored to obtain this gravity. It is always well, therefore, to allow a reasonable range for the gravities of a lubricating oil, giving a high and low limit.

FLASH AND FIRE POINTS

The "Flash-point" of an oil is that temperature to which the oil must be heated, at a specified rate, so that enough vapor is freed from its surface to flash or momentarily ignite when a small flame is applied to it.

The "Fire Test" of an oil is that temperature to which the oil must be heated, at a specified rate, so that it takes fire and burns continuously, when a small flame is applied to its surface.

Methods of Testing.—The tests for flash- and fire-points are usually conducted in a Cleveland open cup tester, as shown in Fig. 12.

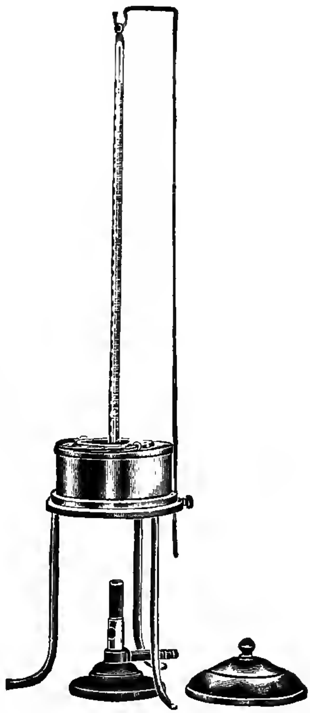


FIG. 12.—Cleveland open cup flash and fire tester.

This instrument consists merely of a solid brass cup, about 2½ inches in diameter and about 1⅛ inches deep. A thermometer is suspended in the centre of the dish. About ¾ inch of the oil to be tested is poured into the cup and heat is applied slowly, so that the temperature of the oil increases at the rate of 10° Fahr. per minute. A small flame from a taper or gas tube is passed across the surface of the oil, when the thermometer indicates 275° Fahr. for engine oils and 425° Fahr. for cylinder oils. The test flame is then applied for every 5° Fahr. rise in temperature, until the vapor momentarily ignites or flashes, which is indicated by a faint puff of blue flame. The temperature is then noted and is the *flashing-point.* The temperature is then increased slowly until the test flame ignites the surface of the oil and causes it to continue to burn. The temperature is noted and is called *the fire-point.*

Usually the fire-point is about 45° to 75° Fahr. higher than the flash-point.

Another method of obtaining the flash- and fire-points is the "closed-cup" method. This test, as the name indicates, is carried on in a closed compartment, heated in the usual manner. The results differ by 15° or 20° lower than the tests obtained by the open-cup method.*

VISCOSITY AND ITS MEASUREMENT

Viscosity.—Viscosity is a measure of fluidity or body. Its value depends upon the internal friction between the particles composing the oil and their resistance to separation. It is closely related to the internal properties of cohesion and adhesion, as described in the section on the "Theory of Lubrication."

Measurement.—Viscosity is measured by means of a viscosimeter. There are various types of viscosimeters on the market. Some depend upon the time required for a given quantity of the oil to flow through an orifice in the bottom of a container. Others are based upon the resistance to motion offered a disk, rotating, immersed in the oil. The rate of flow viscosimeter is the type in most general use.

Saybolt Viscosimeter.—The most widely used instrument for measuring viscosity is the Saybolt viscosimeter. This instrument is essentially composed of a covered oil receptacle of a carefully determined shape and size, provided at the bottom with a standard orifice and a valve, the valve being constructed to quickly open or shut the orifice as desired. The oil cup is supported in an outer cup, which is filled with a pale engine oil of about 375° Fahr. flash-point, or, for some cases, water is used as a bath in the outer cup.

Briefly, the measurement of viscosity with the Saybolt instrument may be described as follows: The oil cup is filled with a standard quantity of the oil to be tested, and after it has been heated to the desired temperature and kept constant for two or three minutes the bottom orifice is opened. The oil is then run into a 60-c.c. flask and the number of seconds, as noted by means of a stop-watch, that are required for the flow of the oil through the orifice into the flask to fill it to the 60-c.c. mark is reported as the viscosity of the oil.

* NOTE.—This difference refers to engine oils. The difference will be greater for high flash test cylinder oils, and it will range as high as 85° or 90° Fahr.

The standard testing temperatures for various oils are as follows:

(*a*) For testing cylinder, valve, and similar oils............212° Fahr.
Note.—This temperature is generally referred to as 212° Fahr. for the temperature of the bath and 210° for the oil.

(*b*) For testing reduced black oils, bath oil, at..............130° Fahr.

(*c*) For testing neutral, spindle, paraffine, red, and other distilled oils, bath and oil, at..........................100° Fahr.

Other Viscosimeters.—The Engler and Tagliabue viscosimeters are used to some extent, but are by no means as generally used as the Saybolt.

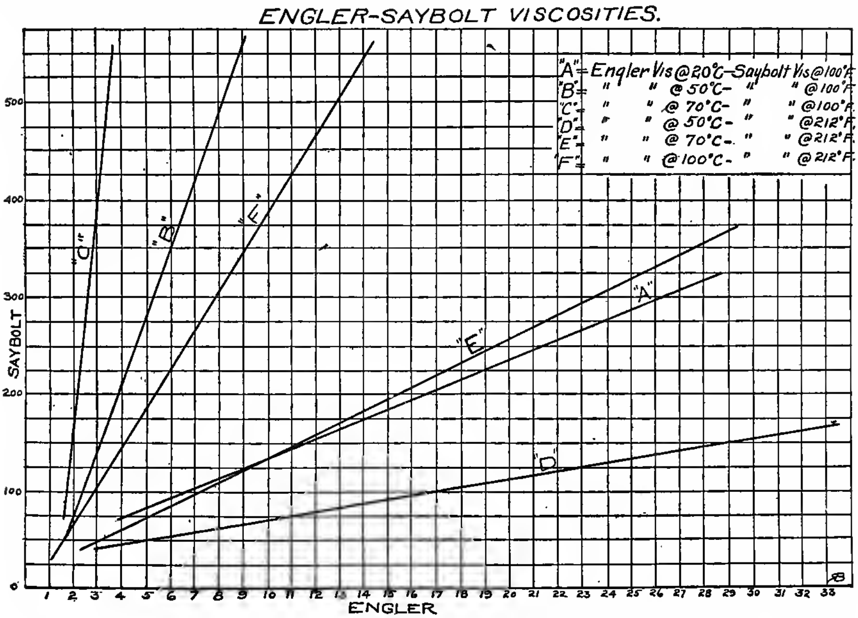


Fig. 13.—Engler-Saybolt viscosities.

For purposes of comparison, some approximate comparative values of Redwood, Engler, Tagliabue, and Saybolt viscosities are shown by the curves in Fig. 13, Fig. 14, and Fig. 15. It must be appreciated, however, that, as these curves were obtained with oils from the Eastern and Mid-Continent crudes, the curves will not be accurate for other oils, especially at high temperatures. It is not practical to obtain absolutely accurate results for comparison of the readings of the various instruments, and the trade is urged to adopt the standard Saybolt instrument, in order to standardize specifications and tests.

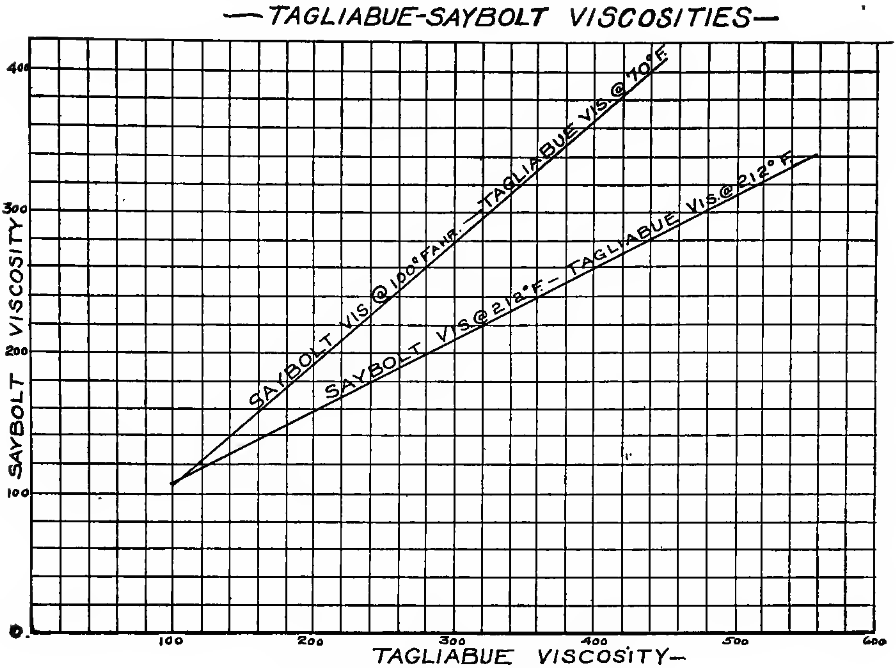


Fig. 14.—Tagliabue-Saybolt viscosities.

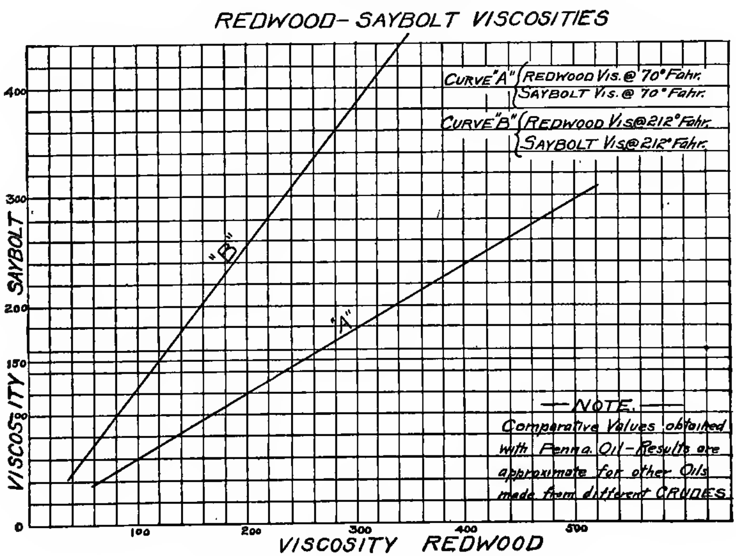


Fig. 15.—Redwood-Saybolt viscosities.

Notes on Viscosity.—The viscosity of petroleum oils decreases as the temperature of the oil increases. The viscosities of lubricating oils made from Texas and California crudes are quite high at the standard testing temperature of 100° Fahr., as compared with the engine and machine oils made from Pennsylvania and Mid-Continent crudes.

The viscosities of lubricating oils made from asphaltic base crudes decrease much faster, as their temperatures are increased, than the viscosities of lubricating oils made from paraffine base crudes.

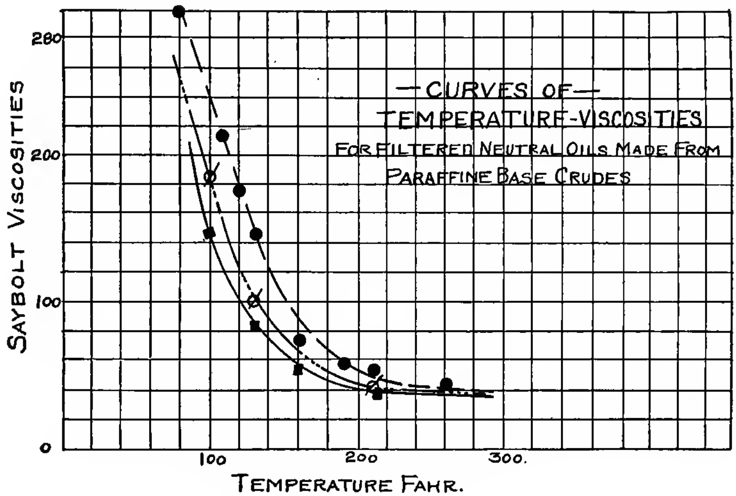


Fig. 16.—Viscosity-temperature curves of filtered neutral oils (paraffine base crudes).

The effect upon the viscosities of various typical neutral oils made from northern crudes is shown in Fig. 16.

A comparison of the changes in the viscosities, with increase in temperatures, of engine oils made from California, Texas, and Pennsylvania crudes, is given by the temperatures-viscosity curves shown in Fig. 5.

The effect of temperature increase upon the viscosities of several cylinder oils is shown by the curves in Fig. 17.

Importance of Viscosity Tests as a Guide to Lubrication.—All operating engineers have had bearings of machines under their care which increased in temperature when in operation, to a certain point and remained at that temperature under normal working conditions. It is not uncommon to find bearings unusually warm and yet causing no worry or anxiety

to the engineer in charge, because he knows that these bearings will not heat to any higher temperatures. These conditions are not evidences of satisfactory lubrication, because excessive frictional heat in a bearing is an indication of loss of power due to an excessive frictional load; the power absorbed by friction having been transformed into heat. The

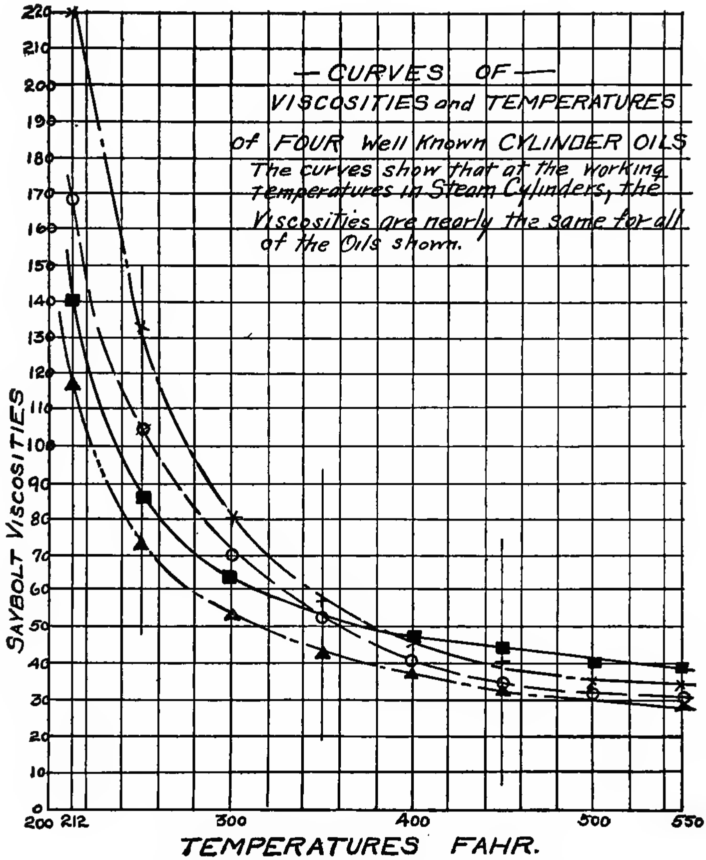


Fig. 17.—Cylinder oils, viscosity-temperature curves.

causes of the high running temperatures in the above-described bearings may be credited largely to the viscosity characteristics of the lubricating oil in use. The viscosity of the oil was too high to give satisfactory results when the bearings were developing normal running heats, and therefore the bearing was required to develop sufficient heat to reduce the

viscosity of the oil to a working value, which allowed it to freely flow into the bearing. With better circulation, the oil was able to balance the production of frictional heat by carrying it away as fast as it was created.

This illustration shows the necessity of using viscosity values, not as a direct guide to the selection of a lubricant, but as an indirect guide. The method of selection of an oil from its viscosity characteristics must be based upon the temperature at which the oil will be expected to work, which in the case of a bearing will be the normal working temperature of the bearing. At this working temperature the viscosity of the oil should fulfil the mechanical and lubricating requirements of the bearing.

By plotting the viscosity-temperature curve of an oil, this selection may be simplified and comparisons made quickly with other oils. An example of the practical use of this method is given as follows:

"Assume an engine bearing to have a normal running temperature of 105° Fahr. when the engine room temperature is 85°. In this case certainly no heat will pass from the air into the bearing. With the exception of the small amount of heat carried away by the engine frame, the 20° excess temperature is a measure of the frictional heat developed in the bearing, and this frictional heat is a measure of wasted energy. If an oil is selected, by means of its viscosity curve, produced from the same crude and having the same viscosity at 85° Fahr. that the oil in use has at 105° Fahr., the friction in the bearing will be reduced, because there will be no necessity for the viscosity of the second oil being reduced to meet the mechanical requirements of the bearing."

It is by far the most efficient practice to use an oil having the lowest viscosity that will insure the maintenance of the lubricating film in a bearing, and excessive viscosity is as much to be avoided as an insufficient supply of oil.

The Value of Viscosity in Steam Cylinder Lubrication.—In the case of steam cylinder lubrication, the viscosity tests of cylinder oils have very little bearing upon the actual lubricating value of the oil.

It has become the custom of engineers and chemists to compare the viscosities of cylinder oils at a temperature of 212° Fahr. (by some at 210° Fahr.). A viscosity at this temperature is totally useless as an indication of the lubricating value of the oil, since no cylinder oil is ever called upon to work at this low temperature. Steam at only 75 pounds pressure has

a temperature of 320° Fahr., while at the usual pressures the temperatures are much higher, as follows:

125 pounds to the square inch	353° Fahr.
150 pounds to the square inch	366° Fahr.
225 pounds to the square inch	397° Fahr.

As can be observed by reference to the curves of viscosities and temperatures of the typical cylinder oils, all of these curves approach a common viscosity as their temperatures are increased. At a temperature of 212° Fahr. their viscosities were widely different, but at 400° Fahr. they were only about 15° apart, and from 400° upwards the viscosities of practically all cylinder oils are the same. The viscosity of a cylinder oil has some bearing upon the rapidity and completeness of atomization of the oil by the incoming steam, but this is more or less of a mechanical action, taking place between the oil and the steam, and is effected largely by the apparatus for introducing the oil into the steam line.

COLD TEST

There are two definitions of Cold Test,—*i.e.,* Cloud Test and Pour Test,—and any reference to cold test should always include the statement of the method used to obtain it.

Cloud Test.—When paraffine base oils are cooled to a low enough temperature, they become cloudy, due to the separation of the finely divided particles of paraffine in the oil. The temperature at which this separation can first be seen is called the Cloud Test of that oil.

When obtaining the Cloud Test, the rate of cooling the oil must be uniform. The oil is usually cooled in a four-ounce sample bottle, having its top broken off. The bottle is placed in a tin holder, with blotting-paper around it to prevent too rapid cooling of the oil. The tin holder is put into a cold brine solution and by means of a special cold test thermometer the temperature is noted at the first clouding of the oil.

Pour Test.—The Pour Test of an oil is the lowest temperature at which the oil will "run." The Pour Test must be very carefully made to obtain any degree of accuracy.

A tube about 1½ inches in diameter and 5 inches long is fitted with a cork with a thermometer pushed through it, so that the bulb is held firmly about an inch from the bottom of the tube. About 2½ inches of oil is poured into the tube and slowly cooled. Every five degrees the tube is tilted, to show whether the oil will run. When it becomes so stiff

that no movement can be noted for ten seconds, the Pour Test is taken as 5° Fahr. above the temperature of the solid oil.

EVAPORATION TEST

To make an evaporation test of an engine oil, a small quantity of the oil is placed in a shallow dish and carefully weighed. The dish is then exposed to a temperature of 212° Fahr. for four hours, after which it is weighed again. No engine oil should show a loss of more than ¼ to ½ per cent. A good cylinder oil, when subjected to a temperature of 400° Fahr. for 24 hours, will not lose more than 2 per cent. in weight.

When specifying the method of conducting an evaporation test, the size of the dish in which the oil is to be tested must be given, in order to make the results obtained of any practical value for comparative purposes. The material of which the dish is made should be stated, and the method of heating the oil, whether in an oven or by steam, must also be known. It is generally best to specify the kind of oven.

The evaporation test of an oil is affected by barometric pressure, and in some cases there will be as much as a 1½ per cent. variation in the results of tests upon the same oil, when taken in different places having considerable difference in barometric pressure.

The most important result, from a practical standpoint, that is obtained from a cylinder oil evaporation test, is the nature and condition of the residue remaining at the end of the test. The percentage of evaporation does not have an important bearing upon cylinder lubrication. The most suitable cylinder oil is the one having a greasy, limpid residue. Any cylinder oil having a sticky, tough residue should be rejected, as such an oil will tend to produce deposits in steam cylinders and give unsatisfactory results.

ACIDITY TESTS

Certain kinds of engine and machine oils are treated with sulphuric acid during the process of refinement. In order to protect the highly polished surfaces of bearings, the lubricating oils used should be examined for acid that may have remained in the oil, due to improper refinement.

An easy test for sulphuric acid is to thoroughly wash a sample of the oil with warm water. Then test the water with neutral litmus paper, and if even a faint reddish tint is shown on the paper the oil should be

rejected. A very small amount of acid will do a large amount of damage to a highly polished surface.

The percentage of acid in any lubricating oil should never exceed $^3/_{10}$ of 1 per cent.*

A simple boiler-room test for acid may be made by immersing a piece of highly polished copper in the oil for twenty-four hours. There should be no change in the brightness of the polished surface. If a trace of acid is present, the surface of the copper will be dulled.

Barium Chloride Test.—Another good test for sulphuric acid can be made by preparing a saturated solution of barium chloride in distilled water. Dilute an ounce of the oil with an equal quantity of high gravity gasoline to make it more limpid, and add six or seven drops of the barium chloride solution. If any sulphuric acid is present, a white deposit or precipitate will be formed.

Free Fatty Acids.—Free fatty acids may exist in the oils used for compounding with mineral oils. They are due to decomposition of the oils during storage in a crude state. Due to their action upon metal, these acids form soaps, which dissolve in the oil and cause gumming.

Organic Acids.—These acids exist naturally in some petroleum crudes, and tests for them must be made by the oil chemist.

TEST FOR TARRY AND OTHER RESIDUES

If it is desirable to test a cylinder oil for tarry residues, the following method may be used:

Dissolve five cubic centimetres of the oil in 95 c.c. of 86° gravity gasoline. Allow the mixture to stand for one hour, and the tar and other insoluble matter will collect at the bottom of the test-tube.

Oxidization of Mineral Oils.—Hirsch, in the *Chemische Zeitung*, 19, page 41, 1895, states that: "Notwithstanding conflicting statements, it is well established that mineral oils oxidize when raised to moderately high temperatures in the air. They may also oxidize at ordinary temperatures when exposed to sunlight, especially in the presence of alkalies."

OTHER TESTS

Test for Animal Oils.—A rough test to determine the presence of animal oils in compound with mineral oils may be made as follows:

Heat two ounces of the oil in a small glass or test-tube, with the same

*Note.—A properly refined lubricating oil should show no traces of sulphuric acid.

quantity of borax, caustic soda, or caustic potash, for fifteen minutes. The presence of animal oil will be shown by a light-yellow deposit.

A quick method of detecting animal oils is to place a few drops of the oil on the palm of the hand and to rub it briskly with the other hand. The heat produced will cause the animal oil to smell if present.

Gumming Test.—The so-called "Gumming Test" for lubricating oils is of little practical value. Trouble due to gumming when using mineral lubricating oil is practically unknown, and the same may be said of evaporation tests.*

For the same viscosities, asphalt base oils have a higher rate of evaporation than paraffine base oils.

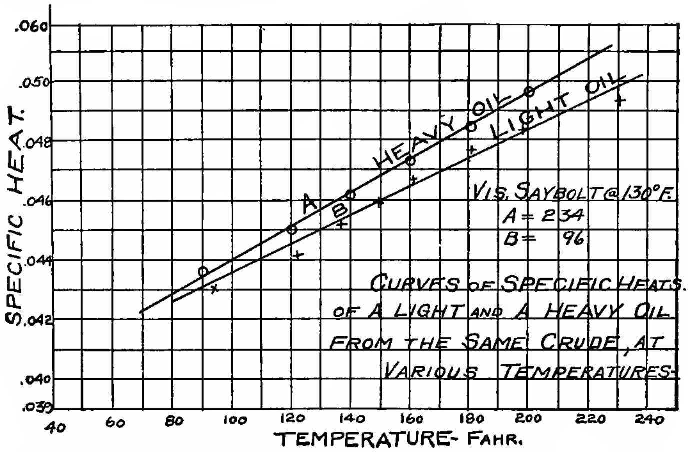


FIG. 18.—Curves of temperatures and specific heats of light and heavy engine oils.

Quality Tests.—A decision may be made as to whether an oil is well refined or not by the following test:

Fill a clean bottle half full of the oil under observation. Heat slowly over an open flame until vapors appear above the oil surface. Maintain the oil at this temperature for 15 minutes. If the oil is well refined, it will darken in color, but remain perfectly clear and free from sediment, after standing for 24 hours, thus proving the absence of acid compounds.

Poorly refined oil will turn jet black under the above-described conditions, and after standing for 24 hours a black carbon-like deposit will appear, showing the presence of sulphuric or sulphonic acid compounds.

* See chapter referring to Depreciation Loss.

THERMAL CAPACITY OF LUBRICATING OILS

There have been some recent investigations made into the relation between the specific heat of an oil and its lubricating qualities with respect to its heat-absorbing properties.

The specific heat of an oil is a measure of its thermal capacity; that is, the quantity of heat the oil must absorb to raise its temperature, one degree Fahrenheit, as compared to the heat required to raise the same volume of water one degree Fahrenheit, when at its maximum density.

The frictional heat developed in a bearing must be absorbed and carried away by the oil, or radiated from the bearing to the air, or conducted off by the engine frame. Claims have been made as to the relative merits of heavy and light oils with regard to their heat-absorbing qualities.

The curves shown in Fig. 18 illustrate the effect of temperature increase on the specific heats of two oils having widely different characteristics. These curves show that the differences are very small and may therefore be neglected.

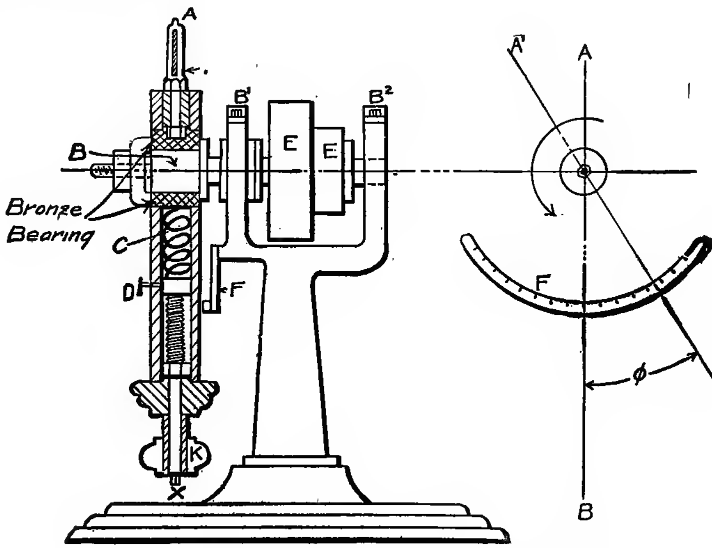


FIG. 19.—Outline drawing of Thurston Railroad Lubricant Tester.

FRICTION TESTING MACHINES

The only true method of learning the value of a lubricant as a friction reducer and its applicability to fulfil a given mechanical requirement is to

submit it to practical tests. In the past these tests have been largely carried out in the laboratory by means of a friction testing machine.

A line drawing of a widely used friction testing machine, known as the Thurston Railroad Lubricant Tester, is shown in Fig. 19.

This machine essentially consists of a shaft revolving between the bearings, B, B^1, B^2. The pressure on B can be regulated by adjusting the coiled spring C. The amount of pressure produced by the coiled spring on the bearing B is indicated by the index pointer D

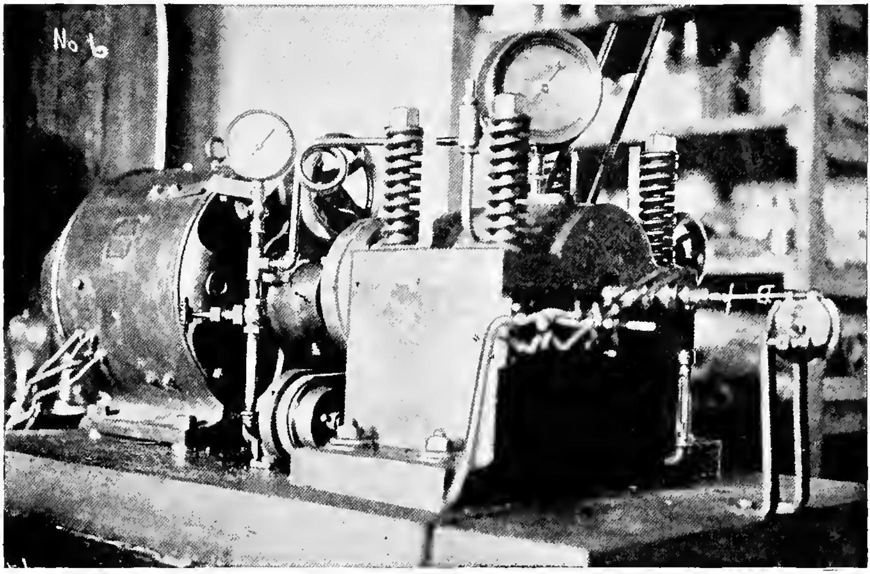


FIG. 20.—Friction testing machine at the United States Naval Experimental Station at Annapolis, Md.

A thermometer T registers the amount of frictional heat generated by the bearing B. The machine is driven by the cone pulley E.

The oil to be tested is introduced into the bearing B in measured quantities. This bearing has the same dimensions as the usual car journal. The pressure on the bearing is brought to the desired intensity by tightening the spring C by means of the nut X.

The friction developed between the rotating journal and the bearing causes a displacement of the pendulum K. The journal is turned at a constant speed. The arc scale F is so graduated that by dividing the

reading of the deflection angle ϕ on the scale F by the pressure shown by the index D, the coefficient of friction is obtained.

This coefficient of friction can then be compared with the results of tests on other oils obtained under the same running conditions on the same machine.

There are several other more highly improved friction testing machines in use.

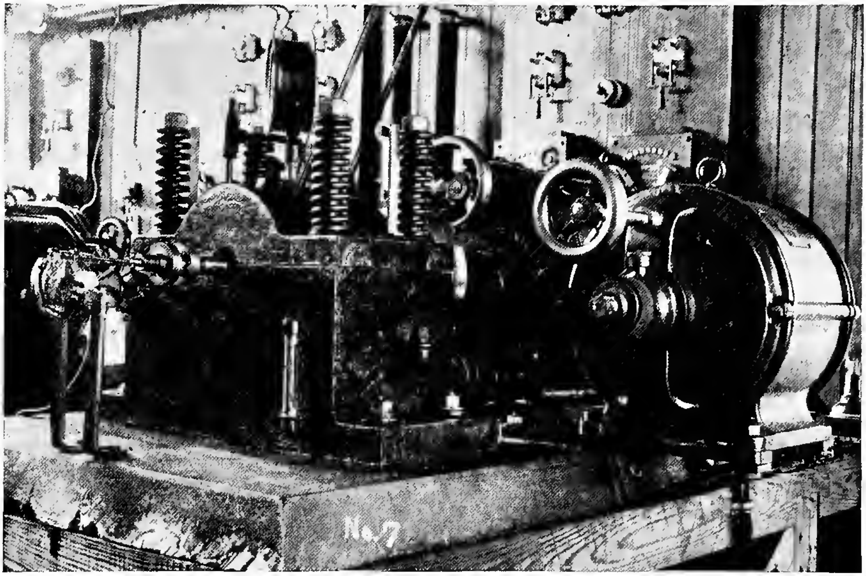


FIG. 21.—Another view of the United States Experimental Station friction testing machine.

Improved Friction Testing Machine.—Figs. 20 and 21 show two views of the friction testing machine designed and used at the United States Naval Experiment Station at Annapolis, Md.

The springs are calibrated. The journal driving motor is of the variable speed type, so that any desired bearing speed may be obtained. A pressure gauge indicates the oil pressure, as supplied by a rotary pump, motor driven, as shown.

The bearing is equipped with an electric heating coil, the electric current being supplied through the " fingers " and rings carried by the small projecting shaft, shown at the side of the bearing.

The pressure in the oil film is indicated by the gauge on top of the bearing cap, as shown.

The oil is drained back into the reservoir below the bearing, and after settling is again pumped to the bearing.

Notes on Testing Machines.—Oils which give satisfactory results on the friction testing machine may act very differently under practical working conditions.

The only similarity between the conditions of actual working requirements and those produced in the testing machine is that of pressure and speed, and in actual use even these conditions are far from being uniform. An oil which works well on the smooth journal of the testing machine may give very poor results under the ordinary conditions of wear. For instance, in case the oil is of such a nature that the heat generated by an abrasion on a working bearing or journal, prevents the oil from reëstablishing the lubricating film readily, the effect is apt to be a "hot box."

Again, the qualities necessary in an oil to permit its feeding properly to all parts to be lubricated are in no way tested by the friction testing machine. Instead of its performance under perfect conditions, it is rather the ability of the oil to meet the abnormal conditions of actual use that determines its value as a lubricant.

The differences in frictional resistance, as shown by the tests of various oils on the friction tester, are due to the viscosities of the oils, and while, for light-bodied oils, such as spindle oils, cotton mill oils, and similar oils, the frictional resistance produced by the viscosities of the oils is of importance, it is of little importance or significance in the case of heavy machinery.

The effect on the coefficient of friction produced by increasing the rubbing speed of the friction machine journal, when the bearing cap pressure and temperature is maintained constant, is shown by curve *A*, Fig. 22.

The effect on the coefficient of friction produced by a variation of the bearing cap pressure, with a constant rubbing speed and bearing temperature, is shown by curve *B* in Fig. 22. Curves *A* and *B* were run on a specially constructed machine, having a heating coil so arranged that the temperature in the bearing was kept constant. A paraffine base, neutral machine oil was used.

It may be added that the constant temperature maintained in the bear-

ing of the above-described tester does not permit of a fair comparison of lubricating oils of different viscosities and made *from different crudes.* If the bearing is maintained at a temperature of 135° Fahr., it gives a distinct advantage to those oils made from asphalt base crudes and imposes a handicap upon those oils made from paraffine base crudes. In one case the result is to reduce the high viscosities of the asphalt base oils to lower and more efficient working viscosities, which required a high bearing temperature; while in the case of the paraffine base oils, having lower

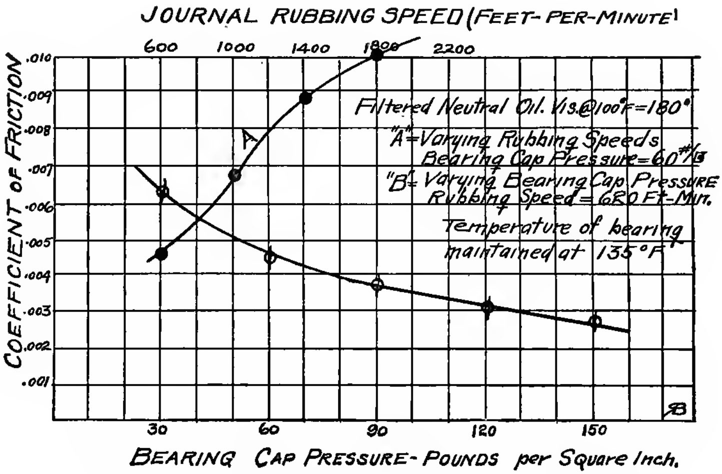


FIG. 22.—Curves showing relation between rubbing speeds, bearing cap pressures, and coefficients of friction.

viscosities at 100° Fahr. than the asphalt oils, it is not practical to compare their coefficients of friction at a temperature much higher than these oils would normally run, since there is no necessity for high bearing heats to reduce their viscosities to the required working values. Results obtained in this manner for comparative purposes mean absolutely nothing and may be likened to a law which is only half stated.

The Failure of Oil Testing Machines.—L. Ubbelohde says in one of his articles on the " Theory of Lubrication ": " The mechanical testing of lubricants is accomplished by determining the coefficients of friction for the oil under observation, by applying it to the journal of the testing machine under varying conditions of velocity, pressure, etc." His investigations have shown that the coefficients of friction as determined on

these machines are dependent upon the viscosities of the oils alone. If, therefore, a number of oils of different viscosities are systematically tested, and the coefficient of friction corresponding to each viscosity is determined for that particular machine, these coefficients of friction will apply without further testing to all oils of the same viscosities, for any particular running temperature."

"The reason that experimenters have not previously recognized this fact, is due to the condition that viscosity has not been expressed in a system of units that is proportional to the viscosity (specific viscosity), but in arbitrary units, which cannot be applied to computation as being proportional to viscosity. Also the relationship existing between temperature and viscosity has not definitely been determined."

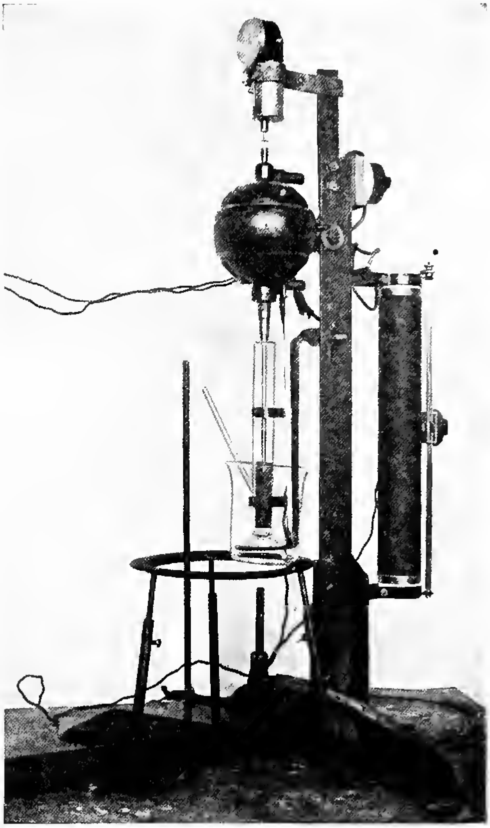


FIG. 23.—Emulsion testing machine.

De-emulsibility Testing for Lubricating Oils.—A de-emulsibility test suggested by the Bureau of Standards consists in stirring 20 c.c. of the oil under observation with 40 c.c. of water, in a cylinder one inch in diameter, for five minutes, at a temperature of 55° C., or 131° Fahr.

The stirring apparatus consists of a flat paddle 3½ inches long and ⅞ inch wide, rotated by an electric motor at 1500 revolutions per minute.

By noting the number of cubic centimetres of the oil that separate out per hour, the de-emulsibility figure of the oil can be determined.

The Bureau recommends that the oil also be allowed to separate out at a temperature of 131° Fahr. (55° Cent.).

For specifications covering lubricating oils for use in turbines (steam), splash-feed, crank-case steam engines, and circulating oiling systems, it is well to incorporate a test for de-emulsibility.

Fig. 23 shows the emulsion testing machine in use at the United States Naval Experimental Station at Annapolis, Md. It may be described as follows:—

A suitable frame (2 inches by 2 inches by one-quarter inch) of angle iron is constructed as shown, to hold the various parts. A tachometer is attached to the top of the frame and connected to the motor shaft. This indicates the speed of the motor. The motor is a direct-current shunt motor (1 ampère, 110 volts, 2400 revolutions per minute), carrying on its lower shaft a set screw and rod. On the end of the rod is a flat paddle. (The paddle is 3½ inches long by ⅞ inch wide and $^1/_{16}$ inch thick.) The rod and paddle extend down into a glass, oil-and-water-containing cylinder, or emulsion cylinder, graduated to 100 c.c. (1¼ inches in diameter and 11 inches high). This graduated cylinder is supported on an iron frame, in a larger glass vessel (4½ inches in diameter and 10 inches high), which provides the emulsion cylinder with a surrounding water-bath.

A rheostat, which is connected in series with the motor armature, can be adjusted to regulate the motor speed.

Brass clips are provided for holding the emulsion cylinder, and also a hook for holding a thermometer in the water-bath for noting the temperature. A motor switch is attached to the upper part of the supporting frame.

The Term "De-emulsibility."—The word "De-emulsibility" is used, because a high numerical value of the rate of settling, as given by the test, indicates a high resistance to emulsification.

GREASE TESTS

Grease may be tested by the following simple tests:

(*a*) The presence of acid may be detected by melting the grease and testing with litmus paper (blue litmus).

(*b*) The evaporation or volatility test may be made by heating a measured quantity of the grease to a temperature of 200° Fahr. for two hours and then weighing the sample to ascertain the loss in weight.

(*c*) A general idea of the extent of the filling, if any, may be had by heating a small quantity of the grease just to the melting-point, and keeping it in a liquid state and perfectly still for an hour. A badly filled grease will leave a residue, its size depending upon the amount of the filling. To obtain any sort of accuracy, this test must be made by a chemist, but an approximate idea of the filling may be had from a field test.

(*d*) To determine whether the grease is alkaline in reaction, melt it to a liquid state, thoroughly stir, and apply a piece of red litmus paper.

PART II

CHAPTER VI

OIL DATA AND MISCELLANEOUS NOTES

Volume of Barrels.—

$V = D^2 \times L \times 0.0034.$ Where V = volume of barrel in gallons.
D = mean diameter of barrel in inches.
L = length in inches.

(Mean diameter equals ½ the sum of the head and bung diameters.)

Rules for Changing Kilogrammes to U. S. Gallons.—(*a*) Refer to Table 10 and change the kilogrammes to pounds.

(*b*) Take the gravity of the oil.

(*c*) Refer to the Gravity-weight Table 11 and pick out the weight corresponding to that gravity.

(*d*) Divide the weight in pounds per gallon into the number of pounds as determined at (*a*), and the result will be in U. S. gallons.

An approximate result may be obtained when changing kilogrammes to U. S. gallons by the following formula:—

0.295 × Number of Kilogrammes = Approximate U. S. Gallons.

The Average Dimensions of a Typical Steel Barrel.—The dimensions of the G*E*M Steel Bilged Barrel, made by the Pressed Steel Products Company, are as follows:—

Capacity	55 gallons
Diameter at bilge	24 inches
Length in inches	35 inches
Weight	100 pounds

Wooden Barrels.—The average wooden barrel weighs when new about 68 pounds and when old about 71 pounds.

Shipping Weights of Cased Oil

One case (2–5-gallon cans to the case)	80 pounds per case
One case (1–5-gallon can to the case)	45 pounds per case
One case (10–1-gallon cans to the case)	90 pounds per case

The following weights may be used as approximate shipping weights:—

Shipping Weights of Greases in Cans and Cases

One case (1–50-pound tin)	61 pounds per case
One case (1–25-pound tin)	32 pounds per case
One case (1–10-pound tin)	14 pounds per case

TABLE 5

Contents of Partially Filled Circular Tanks in United States Gallons

Depth of tank in feet	Diameter of tank in feet																
	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	25
	Capacity of tank in United States gallons																
5	725	1060	1440	1875	2380	2925	3550	4237	4960	5765	6698	7520	9516	11750	14215	16918	18358
6	870	1270	1728	2250	2855	3510	4260	5084	5952	6918	8038	9024	11419	14100	17059	20302	22030
7	1015	1480	2016	2625	3330	4095	4970	5931	6944	8071	9378	10528	13322	16450	19902	23680	25701
8	1160	1690	2304	3000	3805	4680	5680	6778	7936	9224	10718	12032	5225	18800	22745	27070	29372
9	1305	1900	2592	3375	4280	5265	6390	7625	8928	10377	12058	13536	17128	21150	25588	30454	33043
10	1450	2110	2880	3750	4755	5850	7100	8472	9920	11530	13398	15040	19031	23500	28431	33838	36714
11	1595	2320	3168	4125	5230	6435	7810	9319	10912	12683	14738	16544	20934	25850	31274	37222	40385
12	1740	2530	3456	4500	5705	7020	8520	10166	11904	13836	16078	18048	22837	28200	34117	40606	44056
13	1885	2740	3744	4875	6180	7605	9230	11013	12896	14989	17418	19552	24740	30550	36960	43990	47727
14	2030	2950	4032	5250	6655	8190	9940	11860	13888	16142	18758	21056	26643	32900	39803	47374	51398
15	2175	3160	4320	5625	7130	8775	10650	12707	14880	17295	20098	22260	28546	35250	42646	50758	55069
16	2320	3370	4608	6000	7605	9360	11360	13554	15872	18448	21438	24064	30449	37600	45489	54142	58740
17	2465	3580	4896	6375	8080	9945	12070	14401	16864	19601	22778	25568	32352	39950	48332	57520	62411
18	2610	3790	5184	6750	8535	10530	12780	15248	17856	20754	24118	27072	34255	42300	51175	60910	66082
19	2755	4000	5472	7125	9010	11115	13490	16095	18848	21907	25458	28576	36158	44650	54018	64294	09753
20	2900	4210	5760	7500	9490	11700	14200	16942	19840	23060	26798	30080	38062	47000	56861	67678	73424

TABLE 6

Contents of Rectangular Tanks in United States Gallons

For one foot in depth

Width of tank in feet	Length of tank in feet																		
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73	112.21	119.69	127.17	134.65	142.13	149.61	157.09	164.57
2½	......	46.75	56.10	65.45	74.80	84.16	93.51	102.86	112.21	121.56	130.91	140.26	149.61	158.96	168.31	177.66	187.01	196.36	205.71
3	......	......	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09	168.31	179.53	190.75	202.97	213.19	224.41	235.63	246.86
3½	......	......	......	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183.27	196.36	209.45	222.54	235.63	248.73	261.82	274.90	288.00
4	......	......	......	......	119.69	134.65	149.61	164.57	179.53	194.49	209.45	224.41	239.37	254.34	269.30	284.26	299.22	314.18	329.14
4½	......	......	......	......	......	151.48	168.31	185.14	201.97	218.80	235.63	252.47	269.30	286.13	302.96	319.79	336.62	353.45	370.28
5	......	......	......	......	......	......	187.01	205.71	224.41	243.11	261.82	280.52	299.22	317.92	336.62	355.32	374.03	392.72	411.43
5½	......	......	......	......	......	......	......	226.28	246.86	267.43	288.00	308.57	329.14	349.71	370.28	390.85	411.43	432.00	452.57
6	......	......	......	......	......	......	......	......	269.30	291.74	314.18	336.62	359.06	381.50	403.94	426.39	448.83	471.27	493.71
6½	......	......	......	......	......	......	......	......	......	316.05	340.36	364.67	388.98	413.30	437.60	461.92	486.23	510.54	534.85
7	......	......	......	......	......	......	......	......	......	......	366.54	392.72	418.91	445.09	471.27	497.45	523.64	549.81	575.99
7½	......	......	......	......	......	......	......	......	......	......	......	420.78	448.83	476.88	504.93	532.98	561.04	589.08	617.14
8	......	......	......	......	......	......	......	......	......	......	......	......	478.75	508.67	538.59	568.51	598.44	628.36	658.28
8½	......	......	......	......	......	......	......	......	......	......	......	......	......	540.46	572.25	604.05	635.84	667.63	699.42
9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	605.92	639.58	673.25	706.90	740.56
9½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	675.11	710.65	746.17	781.71
10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	748.05	785.45	822.86
10½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	824.73	864.00
11	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	905.14

TABLE 7

Contents, in Cubic Feet and United States Gallons, of Pipes and Cylinders of Various Diameters and One Foot in Length

1 gallon = 231 cubic inches. 1 cubic foot = 7.4805 gallons.

Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity	Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity
1/4	.0003	.0025	....	6	.1963	1.469	61.13
5/16	.0005	.0040	....	6 1/8	.2046	1.531	58.65
3/8	.0008	.0057	....	6 1/4	.2131	1.594	56.31
7/16	.0010	.0078	....	6 3/8	.2217	1.662	54.01
1/2	.0014	.0102	....	6 1/2	.2304	1.724	52.08
9/16	.0017	.0129	....	6 5/8	.2394	1.791	50.13
5/8	.0021	.0159	....	6 3/4	.2485	1.859	48.29
11/16	.0026	.0193	....	6 7/8	.2578	1.928	46.55
3/4	.0031	.0230	....	7	.2673	1.999	44.89
13/16	.0036	.0269	....	7 1/8	.2769	2.071	43.34
7/8	.0042	.0312	....	7 1/4	.2867	2.145	41.86
15/16	.0048	.0359	....	7 3/8	.2967	2.219	40.45
1	.0055	.0408	2181.81	7 1/2	.3068	2.295	39.11
1 1/8	.0069	.0516	1739.13	7 5/8	.3171	2.372	37.84
1 1/4	.0085	.0638	1411.76	7 3/4	.3276	2.450	36.63
1 3/8	.0103	.0770	1165.04	7 7/8	.3382	2.530	35.48
1 1/2	.0123	.0918	975.69	8	.3491	2.611	34.37
1 5/8	.0144	.1077	833.33	8 1/8	.3601	2.694	33.32
1 3/4	.0167	.1249	718.56	8 1/4	.3712	2.777	32.33
1 7/8	.0192	.1436	625.00	8 3/8	.3826	2.862	31.36
2	.0218	.1632	550.44	8 1/2	.3941	2.948	30.45
2 1/8	.0246	.1840	487.80	8 5/8	.4057	3.035	29.58
2 1/4	.0276	.2066	434.76	8 3/4	.4176	3.125	28.74
2 3/8	.0308	.2304	389.52	8 7/8	.4296	3.214	27.93
2 1/2	.0341	.2550	351.84	9	.4418	3.305	27.16
2 5/8	.0376	.2813	319.14	9 1/8	.4541	3.397	26.43
2 3/4	.0412	.3085	291.26	9 1/4	.4667	3.491	25.71
2 7/8	.0451	.3374	266.07	9 3/8	.4794	3.586	25.03
3	.0491	.3672	244.39	9 1/2	.4922	3.682	24.38
3 1/8	.0533	.3987	225.14	9 5/8	.5053	3.780	23.75
3 1/4	.0576	.4309	208.33	9 3/4	.5185	3.879	23.14
3 3/8	.0621	.4645	193.23	9 7/8	.5319	3.979	22.56
3 1/2	.0668	.4998	178.14	10	.5454	4.080	22.00
3 5/8	.0717	.5361	167.36	10 1/8	.5591	4.182	21.46
3 3/4	.0767	.5738	156.45	10 1/4	.5730	4.286	20.94
3 7/8	.0819	.6127	146.52	10 3/8	.5871	4.392	20.44
4	.0873	.6528	137.43	10 1/2	.6013	4.498	19.96
4 1/8	.0928	.6942	129.31	10 5/8	.6157	4.606	19.49
4 1/4	.0985	.7369	121.82	10 3/4	.6303	4.715	19.04
4 3/8	.1044	.7810	114.94	10 7/8	.6450	4.825	18.60
4 1/2	.1104	.8263	108.69	11	.6600	4.937	18.18
4 5/8	.1167	.8727	102.82	11 1/8	.6751	5.050	17.78
4 3/4	.1231	.9206	97.50	11 1/4	.6903	5.164	17.38
4 7/8	.1296	.9695	92.59	11 3/8	.7057	5.279	17.00
5	.1364	1.020	87.98	11 1/2	.7213	5.396	16.63
5 1/8	.1433	1.072	83.74	11 5/8	.7370	5.513	16.28
5 1/4	.1503	1.125	79.84	11 3/4	.7530	5.633	15.94
5 3/8	.1576	1.179	76.14	11 7/8	.7691	5.753	15.60
5 1/2	.1650	1.234	72.73	12	.7854	5.875	15.28
5 5/8	.1726	1.291	69.52	12 1/8	.8018	5.998	14.94
5 3/4	.1803	1.349	66.56	12 1/4	.8184	6.122	14.66
5 7/8	.1883	1.400	63.72	12 3/8	.8352	6.248	14.37

TABLE 7—*Continued*

CONTENTS, IN CUBIC FEET AND UNITED STATES GALLONS, OF PIPES AND CYLINDERS OF VARIOUS DIAMETERS AND ONE FOOT IN LENGTH

1 gallon = 231 cubic inches. 1 cubic foot = 7.4805 gallons.

Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity	Diameter, in inches	For 1 foot in length: Cubic feet; also, area in square feet	For 1 foot in length: United States gallons 231 cubic inches	Length, in inches, of cylinder of 1 cubic foot capacity
12½	.8522	6.375	14.080	21¼	2.463	18.42	4.872
12⅝	.8693	6.503	13.800	21½	2.521	18.86	4.760
12¾	.8866	6.632	13.530	21¾	2.580	19.30	4.651
12⅞	.9041	6.763	13.270	22	2.640	19.75	4.545
13	.9218	6.895	13.020	22¼	2.700	20.20	4.445
13⅛	.9395	7.028	12.780	22½	2.761	20.66	4.347
13¼	.9575	7.163	12.530	22¾	2.823	21.12	4.251
13⅜	.9757	7.299	12.300	23	2.885	21.58	4.160
13½	.994	7.436	12.070	23¼	2.948	22.05	4.070
13⅝	1.013	7.578	11.850	23½	3.012	22.53	3.990
13¾	1.031	7.712	11.640	23¾	3.076	23.01	3.901
13⅞	1.051	7.855	11.420	24	3.142	23.50	3.819
14	1.069	7.997	11.230	25	3.409	25.50	3.520
14⅛	1.088	8.139	11.030	26	3.678	27.58	3.263
14¼	1.107	8.281	10.840	27	3.976	29.74	3.018
14⅜	1.127	8.431	10.650	28	4.276	31.99	2.806
14½	1.147	8.578	10.460	29	4.587	34.31	2.616
14⅝	1.167	8.730	10.280	30	4.909	36.72	2.444
14¾	1.187	8.879	10.110	31	5.241	39.21	2.290
14⅞	1.207	9.029	9.940	32	5.585	41.78	2.149
15	1.227	9.180	9.780	33	5.940	44.43	2.020
15⅛	1.248	9.336	9.620	34	6.305	47.16	1.903
15¼	1.268	9.485	9.460	35	6.681	49.98	1.796
15⅜	1.289	9.642	9.310	36	7.069	52.88	1.698
15½	1.310	9.801	9.160	37	7.467	55.86	1.607
15⅝	1.332	9.964	9.010	38	7.876	58.92	1.527
15¾	1.353	10.121	8.870	39	8.296	62.06	1.446
15⅞	1.374	10.278	8.730	40	8.727	65.28	1.375
16	1.396	10.440	8.600	41	9.168	68.58	1.309
16¼	1.440	10.772	8.330	42	9.621	71.91	1.247
16½	1.485	11.11	8.081	43	10.085	75.44	1.190
16¾	1.530	11.45	7.843	44	10.559	78.99	1.136
17	1.576	11.79	7.511	45	11.045	82.62	1.087
17¼	1.623	12.14	7.394	46	11.451	86.33	1.040
17½	1.670	12.49	7.186	47	12.048	90.13	.996
17¾	1.718	12.85	6.985	48	12.566	94.00	.955
18	1.768	13.22	6.787	49	13.095	97.96	.916
18¼	1.817	13.59	6.604	50	13.635	102.00	.880
18½	1.867	13.96	6.427	51	14.186	106.12	.846
18¾	1.917	14.34	6.259	52	14.748	110.32	.814
19	1.969	14.73	6.094	53	15.320	114.60	.783
19¼	2.021	15.12	5.938	54	15.904	118.97	.755
19½	2.074	15.51	5.786	55	16.499	122.82	.727
19¾	2.128	15.92	5.639	56	17.104	127.95	.702
20	2.182	16.32	5.500	57	17.720	132.55	.677
20¼	2.237	16.73	5.365	58	18.347	137.24	.654
20½	2.292	17.15	5.236	59	18.985	142.02	.632
20¾	2.348	17.56	5.110	60	19.637	146.89	.611
21	2.405	17.99	4.989				

To find the capacity of pipes greater than the largest given in the table, look in the table for a pipe one-half the given size and multiply its capacity by 4, or one of one-third its size, and multiply its capacity by 9, etc.

TABLE 8

Approximate Gravities of Various Crudes

Field	Baumé gravities	Specific gravities
Appalachian (excluding Franklin)	40–48	.8235–.7865
Lima, Indiana	35–40	.8484–.8235
Illinois	28–40	.8860–.8235
Mid-Continent	28–40	.8860–.8235
Colorado (Florence)	30–32	.8750–.8641
Gulf	14–25	.9722–.9032
Corsicanna (excluding Powell)	40	.8235
California	12–30	.9859–.8750

TABLE 9

Conversion Tables for Changing United States Gallons to Litres, or, for Changing Litres to United States Gallons

Conversion of United States Gallons into Litres

Gallons	0	1	2	3	4	5	6	7	8	9
	Litres	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*
0	0.0000	3.7853	7.5706	11.356	15.141	18.946	22.712	26.497	30.282	34.068
10	37.853	41.638	45.423	49.209	52.994	56.799	60.565	64.350	68.135	71.921
20	75.706	79.491	83.276	87.062	90.847	94.652	98.418	102.20	105.99	109.77
30	113.56	117.34	121.13	124.92	128.66	132.50	136.27	140.06	143.84	147.63
40	151.42	155.22	158.99	162.78	166.56	170.36	174.13	177.92	181.70	185.49
50	189.46	193.24	197.03	200.82	204.60	208.40	212.17	215.96	219.74	223.53
60	227.12	230.90	234.69	238.48	242.26	246.06	249.83	253.62	257.40	261.19
70	264.97	268.75	272.54	276.33	280.11	283.91	286.68	291.47	295.25	299.04
80	302.82	306.60	310.39	314.18	317.96	321.76	324.53	329.32	333.10	336.89
90	340.68	344.46	348.25	352.04	355.82	359.62	363.39	367.18	370.96	374.75
100	378.53	382.31	386.10	389.89	393.67	397.47	401.24	405.03	408.81	412.60

Conversion of Litres into United States Gallons

Litres	0	1	2	3	4	5	6	7	8	9
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
0	0.0000	0.2642	0.5284	0.7925	1.0567	1.3209	1.5851	1.8492	2.1134	2.3776
10	2.6418	2.9060	3.1702	3.4343	3.6985	3.9627	4.2269	4.4910	4.7552	5.0194
20	5.2836	5.5478	5.8120	6.0761	6.3403	6.6045	6.8687	7.1328	7.3970	7.6612
30	7.9254	8.1896	8.4538	8.7179	8.9821	9.2463	9.5105	9.8746	10.030	10.303
40	10.567	10.831	11.095	11.360	11.624	11.888	12.152	12.416	12.680	12.945
50	13.209	13.473	13.737	14.002	14.266	14.530	14.794	15.058	15.322	15.587
60	15.851	16.115	16.379	16.644	16.908	17.172	17.436	17.700	17.964	18.229
70	18.492	18.756	19.020	19.284	19.549	19.813	20.077	20.341	20.605	20.870
80	21.134	21.398	21.662	21.926	22.191	22.455	22.719	22.983	23.247	23.512
90	23.776	24.040	24.304	24.568	24.832	25.097	25.361	25.625	25.889	26.154
100	26.418	26.682	26.946	27.210	27.475	27.739	28.003	28.267	28.531	28.796

TABLE 10

Conversion Tables for Changing English Pounds to Kilogrammes, or, for Changing Kilogrammes to English Pounds

The Metric System

Conversion of English Pounds into Kilogrammes

English pounds	0	1	2	3	4	5	6	7	8	9
	Kilo.	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*
0	0.000	0.453	0.907	1.361	1.814	2.268	2.722	3.175	3.629	4.082
10	4.536	4.989	5.443	5.897	6.350	6.804	7.258	7.711	8.165	8.618
20	9.072	9.525	9.979	10.43	10.89	11.34	11.79	12.25	12.70	13.15
30	13.61	14.06	14.52	14.97	15.42	15.88	16.33	16.78	17.24	17.69
40	18.14	18.59	19.05	19.50	19.95	20.41	20.86	21.31	21.77	22.22
50	22.68	23.13	23.59	24.04	24.49	24.95	25.40	25.85	26.31	26.76
60	27.22	27.67	28.13	28.58	29.03	29.49	29.94	30.39	30.85	31.30
70	31.75	32.20	32.66	33.11	33.56	34.02	34.47	34.92	35.38	35.83
80	36.29	36.74	37.20	37.65	38.10	38.56	39.01	39.46	39.92	40.37
90	40.82	41.27	41.73	42.18	42.63	43.09	43.54	43.99	44.45	44.90
100	45.36	45.81	46.27	46.72	47.17	47.63	48.08	48.53	48.99	49.44

Conversion of Kilogrammes into English Pounds

Fr. kilo.	0	1	2	3	4	5	6	7	8	9
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	0.000	2.205	4.410	6.615	8.820	11.02	13.23	15.43	17.64	19.84
10	22.05	24.25	26.46	28.67	30.87	33.07	35.28	37.48	39.69	41.89
20	44.10	46.30	48.51	50.72	52.92	55.12	57.33	59.53	61.74	63.94
30	66.15	68.35	70.56	72.77	74.97	77.17	79.38	81.58	83.79	85.99
40	88.20	90.40	92.61	94.82	97.02	99.22	101.4	103.6	105.8	108.0
50	110.2	112.5	114.6	116.8	119.0	121.2	123.4	125.6	127.8	130.0
60	132.3	134.5	136.7	138.9	141.1	143.3	145.5	147.7	149.9	152.1
70	154.3	156.5	158.7	160.9	163.1	165.3	167.5	169.7	171.9	174.1
80	176.4	178.6	180.8	183.0	185.2	187.4	189.6	191.8	194.0	196.2
90	198.4	200.6	202.8	205.0	207.2	209.4	211.6	213.8	216.0	218.2
100	220.5	222.7	224.9	227.1	229.3	231.5	233.7	235.9	238.1	240.3

TABLE 11

Conversion Table for Changing Baumé Gravity to Specific Gravity, with the Corresponding Pounds per Gallon and Gallons per Pound

Degrees Baumé	Specific gravities	Pounds per gallon	Gallons per pound
10.0	1.000	8.328	0.1201
11.0	.9929	8.269	0.1209
12.0	.9859	8.211	.1218
13.0	.9790	8.153	.1227
14.0	.9722	8.096	.1235
15.0	.9655	8.041	.1244
16.0	.9589	7.986	.1252
17.0	.9524	7.931	.1261
18.0	.9459	7.877	.1270
19.0	.9396	7.825	.1287
20.0	.9333	7.772	.1287
21.0	.9272	7.721	.1295
22.0	.9211	7.670	.1304

TABLE 11—*Continued*

CONVERSION TABLE FOR CHANGING BAUMÉ GRAVITY TO SPECIFIC GRAVITY, WITH THE CORRESPONDING POUNDS PER GALLON AND GALLONS PER POUND

Degrees Baumé	Specific gravities	Pounds per gallon	Gallons per pound
23.0	.9150	7.620	.1313
24.0	.9091	7.570	.1321
25.0	.9032	7.522	.1330
26.0	.8974	7.473	.1338
27.0	.8917	7.425	.1347
28.0	.8861	7.378	.1355
29.0	.8805	7.332	.1364
30.0	.8750	7.286	.1373
31.0	.8696	7.241	.1381
32.0	.8642	7.196	.1390
33.0	.8589	7.152	.1398
34.0	.8537	7.108	.1407
35.0	.8485	7.065	.1415
36.0	.8434	7.022	.1424
37.0	.8383	6.980	.1433
38.0	.8333	6.939	.1441
39.0	.8284	6.989	.1450
40.0	.8235	6.857	.1459
41.0	.8187	6.817	.1467
42.0	.8140	6.777	.1476
43.0	.8092	6.738	.1484
44.0	.8046	6.699	.1493
45.0	.8000	6.661	.1501
46.0	.7955	6.623	.1510
47.0	.7910	6.586	.1518
48.0	.7865	6.548	.1527
49.0	.7821	6.511	.1536
50.0	.7778	6.476	.1544
51.0	.7735	6.440	.1553
52.0	.7692	6.404	.1562
53.0	.7650	6.369	.1570
54.0	.7609	6.334	.1579
55.0	.7568	6.300	.1587

Quick Methods for Extinguishing Oil Fires.—For extinguishing a small oil fire use: Sand, earth, or flour and smother it.

If confined to a small place, break a bottle of ammonia against the burning surface, so that the ammonia gas will settle over the fire and smother it.

Never use water to fight an oil fire.

TABLE 12

CONVERSION TABLES FOR CHANGING FAHRENHEIT THERMOMETER READINGS TO CENTIGRADE READINGS AND CENTIGRADE TO FAHRENHEIT

Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit
−273.00	−460.7	16	60.8	330	626	950	1742	1570	2858
−260.00	−436.0	17	62.6	340	644	960	1760	1580	2876
−250.00	−418.0	18	64.4	350	662	970	1778	1590	2894
−240.00	−400.0	19	66.2	360	680	980	1796	1600	2912
−230.00	−382.0	20	68.0	370	698	990	1814	1610	2930
−220.00	−364.0	21	69.8	380	716	1000	1832	1620	2948
−210.00	−346.0	22	71.6	390	734	1010	1850	1630	2966
−200.00	−328.0	23	73.4	400	752	1020	1868	1640	2984
−190.00	−310.0	24	75.2	410	770	1030	1886	1650	3002
−180.00	−292.0	25	77.0	420	788	1040	1904	1660	3020
−170.00	−274.0	26	78.8	430	806	1050	1922	1670	3038
−160.00	−256.0	27	80.6	440	824	1060	1940	1680	3056
−150.00	−238.0	28	82.4	450	842	1070	1958	1690	3074
−140.00	−220.0	29	84.2	460	860	1080	1976	1700	3092
−130.00	−202.0	30	86.0	470	878	1090	1994	1710	3110
−120.00	−184.0	31	87.8	480	896	1100	2012	1720	3128
−110.00	−166.0	32	89.6	490	914	1110	2030	1730	3146
−100.00	−148.0	33	91.4	500	932	1120	2048	1740	3164
− 90.00	−130.0	34	93.2	510	950	1130	2066	1750	3182
− 80.00	−112.0	35	95.0	520	968	1140	2084	1760	3200
− 70.00	− 94.0	36	96.8	530	986	1150	2102	1770	3218
− 60.00	− 76.0	37	98.6	540	1004	1160	2120	1780	3236
− 50.00	− 58.0	38	100.4	550	1022	1170	2138	1790	3254
− 40.00	− 40.0	39	102.2	560	1040	1180	2156	1800	3272
− 30.00	− 22.0	40	104.0	570	1058	1190	2174	1810	3290
− 20.00	− 4.0	41	105.8	580	1076	1200	2192	1820	3308
− 19.00	− 2.2	42	107.6	590	1094	1210	2210	1830	3326
− 18.00	− 0.4	43	109.4	600	1112	1220	2228	1840	3344
− 17.77	Zero	44	111.2	610	1130	1230	2246	1850	3362
− 17.00	+ 1.4	45	113.0	620	1148	1240	2264	1860	3380
− 16.00	+ 3.2	46	114.8	630	1166	1250	2282	1870	3398
− 15.00	+ 5.0	47	116.6	640	1184	1260	2300	1880	3416
− 14.00	+ 6.8	48	118.4	650	1202	1270	2318	1890	3434
− 13.00	+ 8.6	49	120.2	660	1220	1280	2336	1900	3452
− 12.00	+ 10.4	50	122.0	670	1238	1290	2354	1910	3470
− 11.00	+ 12.2	60	140.0	680	1256	1300	2372	1920	3488
− 10.00	+ 14.0	70	158.0	690	1274	1310	2390	1930	3506
− 9.00	+ 15.8	80	176.0	700	1292	1320	2408	1940	3524
− 8.00	+ 17.6	90	194.0	710	1310	1330	2426	1950	3542
− 7.00	+ 19.4	100	212.0	720	1328	1340	2444	1960	3560
− 6.00	+ 21.2	110	230.0	730	1346	1350	2462	1970	3578
− 5.00	+ 23.0	120	248.0	740	1364	1360	2480	1980	3596
− 4.00	+ 24.8	130	266.0	750	1382	1370	2498	1990	3614
− 3.00	+ 26.6	140	284.0	760	1400	1380	2516	2000	3632
− 2.00	+ 28.4	150	302.0	770	1418	1390	2534	2010	3650
− 1.00	+ 30.2	160	320.0	780	1436	1400	2552	2020	3668
Zero	+ 32.0	170	338.0	790	1454	1410	2570	2030	3686
+ 1	+ 33.8	180	356.0	800	1472	1420	2588	2040	3704
2	35.6	190	374.0	810	1490	1430	2606	2050	3722
3	37.4	200	392.0	820	1508	1440	2624	2060	3740
4	39.2	210	410.0	830	1526	1450	2642	2070	3758
5	41.0	220	428.0	840	1544	1460	2660	2080	3776
6	42.8	230	446.0	850	1562	1470	2678	2090	3794
7	44.6	240	464.0	860	1580	1480	2696	2100	3812
8	46.4	250	482.0	870	1598	1590	2714	2110	3830
9	48.2	260	500.0	880	1616	1500	2732	2120	3848
10	50.0	270	518.0	890	1634	1510	2750	2130	3866
11	51.8	280	536.0	900	1652	1520	2768	2140	3884
12	53.6	290	554.0	910	1670	1530	2786	2150	3902
13	55.4	300	572.0	920	1688	1540	2804	2160	3920
14	57.2	310	590.0	930	1706	1550	2822	2180	3956
15	59.0	320	608.0	940	1724	1560	2840	2200	3992

TABLE 12—*Continued*

CONVERSION TABLES FOR CHANGING FAHRENHEIT THERMOMETER READINGS TO CENTIGRADE READINGS AND CENTIGRADE TO FAHRENHEIT

Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade
− 5	−20.55	57	13.88	119	48.33	181	82.77	243	117.22
− 4	−20.00	58	14.44	120	48.88	182	83.33	244	117.77
− 3	−19.44	59	15.00	121	49.44	183	83.88	245	118.33
− 2	−18.88	60	15.55	122	50.00	184	84.44	246	118.88
− 1	−18.33	61	16.11	123	50.55	185	85.00	247	119.44
Zero	−17.77	62	16.66	124	51.11	186	85.55	248	120.00
+ 1	−17.22	63	17.22	125	51.66	187	86.11	249	120.55
2	−16.66	64	17.77	126	52.22	188	86.66	250	121.11
3	−16.11	65	18.33	127	52.77	189	87.22	251	121.66
4	−15.55	66	18.88	128	53.55	190	87.77	252	122.22
5	−15.00	67	19.44	129	53.88	191	88.33	253	122.77
6	−14.44	68	20.00	130	54.44	192	88.88	254	123.33
7	−13.88	69	20.55	131	55.00	193	89.44	255	123.88
8	−13.33	70	21.11	132	55.55	194	90.00	256	124.44
9	−12.77	71	21.66	133	56.11	195	90.55	257	125.00
10	−12.22	72	22.22	134	56.66	196	91.11	258	125.55
11	−11.66	73	22.77	135	57.22	197	91.66	259	126.11
12	−11.11	74	23.33	136	57.77	198	92.22	260	126.66
13	−10.55	75	23.88	137	58.33	199	92.77	261	127.22
14	−10.00	76	24.44	138	58.88	200	93.33	262	127.77
15	− 9.44	77	25.00	139	59.44	201	93.88	263	128.33
16	− 8.88	78	25.55	140	60.00	202	94.44	264	128.88
17	− 8.33	79	26.11	141	60.55	203	95.00	265	129.44
18	− 7.77	80	26.66	142	61.11	204	95.55	266	130.00
19	− 7.22	81	27.22	143	61.66	205	96.11	267	130.55
20	− 6.66	82	27.77	144	62.22	206	96.66	268	131.11
21	− 6.11	83	28.33	145	62.77	207	97.22	269	131.66
22	− 5.55	84	28.88	146	63.33	208	97.77	270	132.22
23	− 5.00	85	29.44	147	63.88	209	98.33	271	132.77
24	− 4.44	86	30.00	148	64.44	210	98.88	272	133.33
25	− 3.88	87	30.55	149	65.00	211	99.44	273	133.88
26	− 3.33	88	31.11	150	65.55	212	100.00	274	134.44
27	− 2.77	89	31.66	151	66.11	213	100.55	275	135.00
28	− 2.22	90	32.22	152	66.66	214	101.11	276	135.55
29	− 1.66	91	32.77	153	67.22	215	101.66	277	136.11
30	− 1.11	92	33.33	154	67.77	216	102.22	278	136.66
31	− .55	93	33.88	155	68.33	217	102.17	279	137.22
32	Zero	94	34.44	156	68.88	218	103.33	280	137.77
33	+ .55	95	35.00	157	69.44	219	103.88	281	138.33
34	1.11	96	35.55	158	70.00	220	104.44	282	138.88
35	1.66	97	36.11	159	70.55	221	105.00	283	139.44
36	2.22	98	36.66	160	71.11	222	105.55	284	140.00
37	2.77	99	37.22	161	71.66	223	106.11	285	140.55
38	3.33	100	37.77	162	72.22	224	106.66	286	141.11
39	3.88	101	38.33	163	72.77	225	107.22	287	141.66
40	4.44	102	38.88	164	73.33	226	107.77	288	142.22
41	5.00	103	39.44	165	73.88	227	108.33	289	142.77
42	5.55	104	40.00	166	74.44	228	108.88	290	143.33
43	6.11	105	40.55	167	75.00	229	109.44	291	143.88
44	6.66	106	41.11	168	75.55	230	110.00	292	144.44
45	7.22	107	41.66	169	76.11	231	110.55	293	145.00
46	7.77	108	42.22	170	76.66	232	111.11	294	145.55
47	8.33	109	42.77	171	77.22	233	111.66	295	146.11
48	8.88	110	43.33	172	77.77	234	112.22	296	146.66
49	9.44	111	43.88	173	78.33	235	112.77	297	147.22
50	10.00	112	44.44	174	78.88	236	113.33	298	147.77
51	10.55	113	45.00	175	79.44	237	113.88	299	148.33
52	11.11	114	45.55	176	80.00	238	114.44	300	148.88
53	11.66	115	46.11	177	80.55	239	115.00	400	204.44
54	12.22	116	46.66	178	81.11	240	115.55	600	315.55
55	12.77	117	47.22	179	81.66	241	116.11	800	433.33
56	13.33	118	47.77	180	82.22	242	116.66	1000	537.77

TABLE 13

Areas and Circumferences of Circles (By Sixteenths to 5)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
1/64	.049087	.00019						
1/32	.098175	.00077	1.	3.14159	.78540	3.	9.42478	7.0686
3/64	.147262	.00173	1/16	3.33794	.88664	1/16	9.62113	7.3662
1/16	.196350	.00307	1/8	3.53429	.99402	1/8	9.81748	7.6699
3/32	.294524	.00690	3/16	3.73064	1.1075	3/16	10.0138	7.9798
1/8	.392699	.01227	1/4	3.92699	1.2272	1/4	10.2102	8.2958
5/32	.490874	.01917	5/16	4.12334	1.3530	5/16	10.4065	8.6179
3/16	.589049	.02761	3/8	4.31969	1.4849	3/8	10.6029	8.9462
7/32	.687223	.03758	7/16	4.51604	1.6230	7/16	10.7992	9.2806
1/4	.785398	.04909	1/2	4.71239	1.7671	1/2	10.9956	9.6211
9/32	.883573	.06213	9/16	4.90874	1.9175	9/16	11.1919	9.9678
5/16	.981748	.07670	5/8	5.10509	2.0739	5/8	11.3883	10.321
11/32	1.07992	.09281	11/16	5.30144	2.2365	11/16	11.5846	10.680
3/8	1.17810	.11045	3/4	5.49779	2.4053	3/4	11.7810	11.045
13/32	1.27627	.12962	13/16	5.69414	2.5802	13/16	11.9773	11.416
7/16	1.37445	.15033	7/8	5.89049	2.7612	7/8	12.1737	11.793
15/32	1.47262	.17257	15/16	6.08684	2.9483	15/16	12.3700	12.177
1/2	1.57080	.19635	2.	6.28319	3.1416	4.	12.5664	12.566
17/32	1.66897	.22166	1/16	6.47953	3.3410	1/16	12.7627	12.962
9/16	1.76715	.24850	1/8	6.67588	3.5466	1/8	12.9591	13.364
19/32	1.86532	.27688	3/16	6.87223	3.7583	3/16	13.1554	13.772
5/8	1.96350	.30680	1/4	7.06858	3.9761	1/4	13.3518	14.186
21/32	2.06167	.33824	5/16	7.26493	4.2000	5/16	13.5481	14.607
11/16	2.15984	.37122	3/8	7.46128	4.4301	3/8	13.7445	15.033
23/32	2.25802	.40574	7/16	7.65763	4.6664	7/16	13.9408	15.466
3/4	2.35619	.44179	1/2	7.85398	4.9087	1/2	14.1372	15.904
25/32	2.45437	.47937	9/16	8.05033	5.1572	9/16	14.3335	16.349
13/16	2.55254	.51849	5/8	8.24668	5.4119	5/8	14.5299	16.800
27/32	2.65072	.55914	11/16	8.44303	5.6727	11/16	14.7262	17.257
7/8	2.74889	.60132	3/4	8.63938	5.9396	3/4	14.9226	17.721
29/32	2.84707	.64504	13/16	8.83573	6.2126	13/16	15.1189	18.190
15/16	2.94524	.69029	7/8	9.03208	6.4918	7/8	15.3153	18.665
31/32	3.04342	.73708	15/16	9.22843	6.7771	15/16	15.5116	19.147
1.	3.14159	.78540	3.	9.42478	7.0686	5.	15.7080	19.635

TABLE 14

Areas and Circumferences of Circles (By Eighths from 5–11)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
5.	15.7080	19.635	6.	18.8496	28.274	7.	21.9911	38.485
1/8	16.1007	20.629	1/8	19.2423	29.465	1/8	22.3838	39.871
1/4	16.4934	21.648	1/4	19.6350	30.680	1/4	22.7765	41.282
3/8	16.8861	22.691	3/8	20.0277	31.919	3/8	23.1692	42.718
1/2	17.2788	23.758	1/2	20.4204	33.183	1/2	23.5619	44.179
5/8	17.6715	24.850	5/8	20.8131	34.472	5/8	23.9546	45.664
3/4	18.0642	25.967	3/4	21.2058	35.785	3/4	24.3473	47.173
7/8	18.4569	27.109	7/8	21.5984	37.122	7/8	24.7400	48.707
6.	18.8496	28.274	7.	21.9911	38.485	8.	25.1327	50.265

TABLE 14—*Continued*

AREAS AND CIRCUMFERENCES OF CIRCLES (BY EIGHTHS FROM 5–11)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
8.	25.1327	50.265	9.	28.2743	63.617	10.	31.4159	78.540
⅛	25.5254	51.849	⅛	28.6670	65.397	⅛	31.8086	80.516
¼	25.9181	53.456	¼	29.0597	67.201	¼	32.2013	82.516
⅜	26.3108	55.088	⅜	29.4524	69.029	⅜	32.5940	84.541
½	26.7035	56.745	½	29.8451	70.882	½	32.9867	86.590
⅝	27.0962	58.426	⅝	30.2378	72.760	⅝	33.3794	88.664
¾	27.4889	60.132	¾	30.6305	74.662	¾	33.7721	90.763
⅞	27.8816	61.862	⅞	31.0232	76.589	⅞	34.1648	92.886
9.	28.2743	63.617	10.	31.4159	78.540	11.	34.5575	95.933

TABLE 15

CIRCUMFERENCES AND AREAS OF CIRCLES (1–150)

Diameter	Circumference ○	Area ●	Diameter	Circumference ○	Area ●	Diameter	Circumference ○	Area ●
1	3.1416	0.7854	51	160.22	2042.8	101	317.30	8011.9
2	6.2832	3.1416	52	163.36	2123.7	102	320.44	8171.3
3	9.4248	7.0686	53	166.50	2206.2	103	323.58	8332.3
4	12.566	12.5664	54	169.65	2290.2	104	326.73	8494.9
5	15.708	19.6350	55	172.79	2375.8	105	329.87	8659.0
6	18.850	28.2743	56	175.93	2463.0	106	333.01	8824.7
7	21.991	38.4845	57	179.07	2551.8	107	336.15	8992.0
8	25.133	50.2655	58	182.21	2642.1	108	339.29	9160.9
9	28.274	63.6173	59	185.35	2734.0	109	342.43	9331.3
10	31.416	78.54	60	188.50	2827.4	110	345.58	9503.3
11	34.558	95.03	61	191.64	2922.5	111	348.72	9676.9
12	37.699	113.10	62	194.78	3019.1	112	351.86	9852.0
13	40.841	132.73	63	197.92	3117.2	113	355.00	10028.8
14	43.982	153.94	64	201.06	3217.0	114	358.14	10207.0
15	47.124	176.71	65	204.20	3318.3	115	361.28	10386.9
16	50.265	201.06	66	207.35	3421.2	116	364.42	10568.3
17	53.407	226.98	67	210.49	3525.7	117	367.57	10751.3
18	56.549	254.47	68	213.63	3631.7	118	370.71	10935.9
19	59.690	283.53	69	216.77	3739.3	119	373.85	11122.0
20	62.832	314.16	70	219.91	3848.5	120	376.99	11310
21	65.973	346.36	71	223.05	3959.2	121	380.13	11499
22	69.115	380.13	72	226.19	4071.5	122	383.27	11690
23	72.257	415.48	73	229.34	4185.4	123	386.42	11882
24	75.398	452.39	74	232.48	4300.8	124	389.56	12076
25	78.540	490.87	75	235.62	4417.9	125	392.70	12272
26	81.681	530.93	76	238.76	4536.5	126	395.84	12469
27	84.823	572.56	77	241.90	4656.6	127	398.98	12668
28	87.965	615.75	78	245.04	4778.4	128	402.12	12868
29	91.106	660.52	79	248.19	4901.7	129	405.27	13070
30	94.248	706.86	80	251.33	5026.6	130	408.41	13273
31	97.389	754.77	81	254.47	5153.0	131	411.55	13478
32	100.53	804.25	82	257.61	5281.0	132	414.69	13685
33	103.67	855.30	83	260.75	5410.6	133	417.83	13893
34	106.81	907.92	84	263.89	5541.8	134	420.97	14103
35	109.96	962.11	85	267.04	5674.5	135	424.12	14314
36	113.10	1017.88	86	270.18	5808.8	136	427.26	14527
37	116.24	1075.21	87	273.32	5944.7	137	430.40	14741
38	119.38	1134.11	88	276.46	6082.1	138	433.54	14957
39	122.52	1194.59	89	279.60	6221.1	139	436.68	15175
40	125.66	1256.63	90	282.74	6361.7	140	439.82	15394
41	128.81	1320.25	91	285.88	6503.9	141	442.96	15615
42	131.95	1385.44	92	289.03	6647.6	142	446.11	15837
43	135.09	1452.20	93	292.17	6792.9	143	449.25	16061
44	138.23	1520.56	94	295.31	6939.8	144	452.39	16286
45	141.37	1590.43	95	298.45	7088.2	145	455.53	16513
46	144.51	1661.90	96	301.59	7238.2	146	458.67	16742
47	147.65	1734.94	97	304.73	7389.8	147	461.81	16972
48	150.80	1809.55	98	307.88	7543.0	148	464.96	17203
49	153.94	1885.74	99	311.02	7697.7	149	468.10	17437
50	157.08	1963.50	100	314.16	7854.0	150	471.24	17671

TABLE 16

Areas and Circumferences of Circles (By Tenths up to 18)

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
0.0	.00000	.000000	6.0	18.8496	28.2743	12.0	37.6991	113.0972
.1	.31416	.007854	.1	19.1637	29.2247	.1	38.0133	114.9901
.2	.62832	.031416	.2	19.4779	30.1907	.2	38.3274	116.8987
.3	.94248	.070686	.3	19.7920	31.1725	.3	38.6416	118.8229
.4	1.2566	.12566	.4	20.1062	32.1699	.4	38.9557	120.7628
.5	1.5708	.19635	.5	20.4204	33.1831	.5	39.2699	122.7185
.6	1.8850	.28274	.6	20.7345	34.2119	.6	39.5841	124.6898
.7	2.1991	.38385	.7	21.0487	35.2565	.7	39.8982	126.6769
.8	2.5133	.50266	.8	21.3628	36.3168	.8	40.2124	128.6796
.9	2.8274	.63617	.9	21.6770	37.3928	.9	40.5265	130.6981
1.0	3.1416	.7854	7.0	21.9911	38.4845	13.0	40.8407	132.7323
.1	3.4558	.9503	.1	22.3053	39.5919	.1	41.1549	134.7822
.2	3.7699	1.1310	.2	22.6195	40.7150	.2	41.4690	136.8478
.3	4.0841	1.3273	.3	22.9336	41.8539	.3	41.7832	138.9291
.4	4.3982	1.5394	.4	23.2478	43.0084	.4	42.0973	141.0261
.5	4.7124	1.7671	.5	23.5619	44.1786	.5	42.4115	143.1388
.6	5.0265	2.0106	.6	23.8761	45.3646	.6	42.7257	145.2672
.7	5.3407	2.2698	.7	24.1903	46.5663	.7	43.0398	147.4114
.8	5.6549	2.5447	.8	24.5044	47.7836	.8	43.3540	149.5712
.9	5.9690	2.8353	.9	24.8186	49.0167	.9	43.6681	151.7468
2.0	6.2832	3.1416	8.0	25.1327	50.2655	14.0	43.9823	153.9380
.1	6.5973	3.4636	.1	25.4469	51.5300	.1	44.2965	156.1450
.2	6.9115	3.8013	.2	25.7611	52.8102	.2	44.6106	158.3677
.3	7.2257	4.1548	.3	26.0752	54.1061	.3	44.9248	160.6061
.4	7.5398	4.5239	.4	26.3894	55.4177	.4	45.2389	162.8602
.5	7.8540	4.9087	.5	26.7035	56.7450	.5	45.5531	165.1300
.6	8.1681	5.3093	.6	27.0177	58.0880	.6	45.8673	167.4155
.7	8.4823	5.7256	.7	27.3319	59.4468	.7	46.1814	169.7167
.8	8.7965	6.1575	.8	27.6460	60.8212	.8	46.4956	172.0336
.9	9.1106	6.6052	.9	27.9602	62.2114	.9	46.8097	174.3662
3.0	9.4248	7.0686	9.0	28.2743	63.6173	15.0	47.1239	176.7146
.1	9.7389	7.5477	.1	28.5885	65.0388	.1	47.4380	179.0786
.2	10.0531	8.0425	.2	28.9027	66.4761	.2	47.7522	181.4584
.3	10.3673	8.5530	.3	29.2168	67.9291	.3	48.0664	183.8539
.4	10.6814	9.0792	.4	29.5310	69.3978	.4	48.3805	186.2650
.5	10.9956	9.6211	.5	29.8451	70.8822	.5	48.6947	188.6919
.6	11.3097	10.1788	.6	30.1593	72.3823	.6	49.0088	191.1345
.7	11.6239	10.7521	.7	30.4734	73.8981	.7	49.3230	193.5928
.8	11.9381	11.3411	.8	30.7876	75.4296	.8	49.6372	196.0668
.9	12.2522	11.9459	.9	31.1018	76.9769	.9	49.9513	198.5565
4.0	12.5664	12.5664	10.0	31.4159	78.5398	16.0	50.2655	201.0619
.1	12.8805	13.2025	.1	31.7301	80.1185	.1	50.5796	203.5831
.2	13.1947	13.8544	.2	32.0442	81.7128	.2	50.8938	206.1199
.3	13.5088	14.5220	.3	32.3584	83.3229	.3	51.2080	208.6724
.4	13.8230	15.2053	.4	32.6726	84.9487	.4	51.5221	211.2407
.5	14.1372	15.9043	.5	32.9867	86.5901	.5	51.8363	213.8246
.6	14.4513	16.6190	.6	33.3009	88.2473	.6	52.1504	216.4243
.7	14.7655	17.3494	.7	33.6150	89.9202	.7	52.4646	219.0397
.8	15.0796	18.0956	.8	33.9292	91.6088	.8	52.7788	221.6708
.9	15.3938	18.8574	.9	34.2434	93.3132	.9	53.0929	224.3176
5.0	15.7080	19.6350	11.0	34.5575	95.0332	17.0	53.4071	226.9801
.1	16.0221	20.4282	.1	34.8717	96.7689	.1	53.7212	229.6583
.2	16.3363	21.2372	.2	35.1858	98.5203	.2	54.0354	232.3522
.3	16.6504	22.0618	.3	35.5000	100.2875	.3	54.3495	235.0618
.4	16.9646	22.9022	.4	35.8142	102.0703	.4	54.6637	237.7871
.5	17.2788	23.7583	.5	36.1283	103.8689	.5	54.9779	240.5282
.6	17.5929	24.6301	.6	36.4425	105.6832	.6	55.2920	243.2849
.7	17.9071	25.5176	.7	36.7566	107.5132	.7	55.6062	246.0574
.8	18.2212	26.4208	.8	37.0708	109.3588	.8	55.9203	248.8456
.9	18.5354	27.3397	.9	37.3850	111.2202	.9	56.2345	251.6494
6.0	18.8496	28.2743	12.0	37.6991	113.0973	18.0	56.5487	254.4690

Circles

Notation.

d = diameter of the circle.	c = chord of a segment, length of.
r = radius of the circle.	h = height of a segment.
p = periphery or circumference.	s = side of a regular polygon.
a = area of a circle or part thereof.	v = centre angle.
b = length of a circle-arc.	w = polygon angle.

All measures must be expressed in terms of the same unit.

Formulas for the Circle

Periphery or Circumference	*Diameter and Radius*	*Area of the Circle*
$p = \pi d = 3.14d.$	$d = \frac{p}{2\pi} = \frac{p}{3.14}.$	$a = \frac{\pi d^2}{4} = 0.7854d^2.$
$p = 2\pi r = 6.28r.$	$r = \frac{p}{2\pi} = \frac{p}{6.28}.$	$a = \pi r^2 = 3.14r^2.$
$p = 2\sqrt{\pi a} = 3.54\sqrt{a}.$	$d = 2\sqrt{\frac{a}{\pi}} = 1.128\sqrt{a}.$	$a = \frac{p^2}{4\pi} = \frac{p^2}{12.56}.$
$p = \frac{2a}{r} = \frac{4a}{d}.$	$r = \sqrt{\frac{a}{\pi}} = 0.564\sqrt{a}.$	$a = \frac{pr}{2} = \frac{pd}{4}.$

π = 3.141 592 653 589 793 238 462 643 383 279 502 884 197 169 399

2π = 6.283 185	$\frac{1}{4}\pi$ = 0.785 398	$\frac{1}{\pi}$ = 0.318 310	$\frac{360}{\pi}$ = 114.5915
3π = 9.424 778	$\frac{1}{3}\pi$ = 1.047 197	$\frac{2}{\pi}$ = 0.636 619	π^2 = 9.869 650
4π = 12.566 370	$\frac{1}{2}\pi$ = 1.570 796	$\frac{3}{\pi}$ = 0.954 929	$\sqrt{\pi}$ = 1.772 453
5π = 15.707 963	$\frac{1}{8}\pi$ = 0.392 699	$\frac{4}{\pi}$ = 1.273 239	$\sqrt{\frac{1}{\pi}}$ = 0.564 189
6π = 18.849 556	$\frac{1}{6}\pi$ = 0.523 599	$\frac{6}{\pi}$ = 1.909 859	$\sqrt{\frac{\pi}{2}}$ = 1.253 314
7π = 21.991 148	$\frac{1}{12}\pi$ = 0.261 799	$\frac{8}{\pi}$ = 2.546 478	$\sqrt{\frac{2}{\pi}}$ = 0.797 884
8π = 25.132 741	$\frac{2}{3}\pi$ = 2.094 394	$\frac{12}{\pi}$ = 3.819 718	
9π = 28.274 334	$\frac{1}{360}\pi$ = 0.008 726		

Log. π = 0.497 149 872 69413

TABLE No. 16 (A)

Approximate Weights of Steel Barrels with Oil of Various Gravities

Baumé gravity	Weight of barrel and oil in pounds
16	531
18	525
22	514
25	507
30	493
35	482
40	470

* Note.—Capacity 55 gallons, less one gallon out, makes 54 gallons.

TABLE 16 (B)

U. S. STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL

Gauge of tank, metal	Thickness in fractions of an inch
10	9/64
11	1/8
12	7/64
16	1/16

BUYING AND SELLING OILS BY WEIGHT

Advantages of Checking Oil Gallonage by Weight.—(*a*) All measurements can be referred to a standard volume, at 60° Fahr.

(*b*) Less liability of personal error.

(*c*) Quicker than checking by gallonage method.

(*d*) Can be made very accurate and yet be made rapidly.

(*e*) Assurance that the gallonage obtained is correct, regardless as to whether the oil has been expanded by heat or contracted by cold.

Method of Operation.—(*a*) Take the gross weight of the Barrel and Oil combined.

(*b*) Empty the barrel and allow it to thoroughly drain.

(*c*) Take Gravity and Temperature of the oil, with a Hydrometer and Thermometer.

(*d*) Weigh the empty barrel (Tare weight).

(*e*) Refer to Gravity Table No. 11 and select the corresponding weight per gallon, as indicated by the gravity reading, when corrected for the number of degrees above or below 60° Fahr. (See temperature correction table, under Gravity.)

If W_1 = Weight of the Barrel and Oil.

W_2 = Weight of the Barrel when *drained* empty.

W_3 = Weight of the Oil.

B = Weight of one gallon of the Oil at the corrected gravity.

Then: $W_1 - W_2 = W_3$.

$\frac{W_3}{B}$ = Correct Gallonage of the Oil.

Interest Tables.—To find the interest on any principal, for any number of days, figuring 30 days to the month and 360 days to the year. If the principal contains cents, point off four places from the right of the result, to express the interest in dollars and cents. When the principal contains cents, point off only two places.

At 3 per cent., multiply the principal by the number of days and divide by......... 120
At 4 per cent., multiply by the number of days and divide by........ 90
At 5 per cent., multiply by the number of days and divide by..................... 72
At 6 per cent., multiply by the number of days and divide by..................... 60
At 7 per cent., multiply by the number of days and divide by..................... 52
At 8 per cent., multiply by the number of days and divide by..................... 45
At 9 per cent., multiply by the number of days and divide by..................... 40
At 10 per cent., multiply by the number of days and divide by..................... 36

The Effect of Air Bubbles in Bearing Lubricating Oil.—An English engineer has investigated the creeping of oil over the outside surfaces of bearings and the results of his findings are included below without comment as to their merits.

He states as follows: " Oil used as a lubricant creeps over the outer surfaces of a bearing, even at ordinary temperatures, due to the fact that air is drawn into the oil, by the rotative action of the journal and due to the rapid flow of the oil in the feed pipes. This air spreads through the body of the oil in the form of finely divided bubbles. These bubbles burst when they come to the surface and form a fine spray, which settles on the exterior of the bearing, causing a resulting waste of oil."

" The investigator recommends, that the return pipes from bearings be made oversize and large enough to carry off the expanded volume of oil and bubbles, or that a vent pipe opening out at a higher level than the oil supply tank, be provided to remedy the trouble."

Approximate Costs of Steam Engines.—When estimating the " Cost of Producing Power" in any plant, it is necessary to know the approximate cost of the plant equipment, so that an " Interest Charge " and " Depreciation Allowance " may be added to the cost of fuel, labor, etc., to give the total cost of producing a " Horse-power Per Year " in that plant. The following figures give approximated costs of various engines, as follows:

Simple Slide Valve Engines.................	\$7.00–\$10.00 per H. P.
Simple Corliss Engines......................	\$11.00–\$13.00 per H. P.
Compound Slide Valve Engines..............	\$12.00–\$1500 per H. P.
Compound Corliss Engines..................	\$18.00–\$23.00 per H. P.
High Speed Slide Automatic Engines.........	\$10.00–\$13.00 per H. P.
Low Speed Automatic Engines...............	\$15.00–\$17.00 per H. P.

Horse-power Costs at the Various Machines in a Plant.—In the usual well-designed plant, with no unusually long transmission shafting and with properly proportioned pulleys, etc., a horse-power should be deliv-

ered to any machine or other consumer of power for every one and one-quarter horse-power delivered by the engine.

This would make the cost for power, in a well-lubricated plant, 25 per cent. greater at the machines than at the engine, and this fact should be borne in mind when considering the resulting saving in power costs by efficient lubrication of machinery. This fact will also illustrate the necessity for efficient and economical lubrication of shafting, to prevent this differential exceeding the 25 per cent. mark.

NOTES ON PETROLEUM INDUSTRY

According to the United States Bureau of the Census, preliminary reports, the value of the annual production of the petroleum industry increased 67.2 per cent. between 1909–1914. The total cost of Crude Petroleum increased 64 per cent. between those years. Lubricating oils show a decrease in quantity and an increase in value—from 10,745,880 barrels valued at $38,884,236 to 10,348,521 barrels valued at $55,812,120. Other products, including residuum or tar, greases, paraffine wax and other by-products, increased in value from $27,331,571 to $37,805,610, or 38.2 per cent.

The production of naphthas and lighter products, chiefly gasoline, increased from $39,771,959 to $121,919,307.

By reference to the above relative values of the costs and production of lubricating oils and other petroleum products, the importance of improved and more efficient methods, in the purchasing and application of lubricating products, may be appreciated.

TABLE 17

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
4	.264	.328	5	.330	.410
.1	.271	.336	.1	.337	.418
.2	.277	.344	.2	.343	.426
.3	.284	.353	.3	.350	.435
.4	.290	.361	.4	.357	.443
.5	.297	.369	.5	.363	.451
.6	.304	.377	.6	.370	.459
.7	.310	.385	.7	.376	.467
.8	.317	.394	.8	.383	.476
.9	.323	.402	.9	.389	.484

TABLE 17—*Continued*

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
6	.396	.492	10.3	.680	.845
.1	.403	.500	.4	.686	.853
.2	.409	.508	.5	.693	.861
.3	.416	.517	.6	.700	.869
.4	.422	.525	.7	.706	.877
.5	.429	.533	.8	.713	.886
.6	.436	.541	.9	.719	.894
.7	.442	.549	11	.726	.902
.8	.449	.558	.1	.733	.910
.9	.455	.566	.2	.739	918
7	.462	.574	.3	.746	.927
.1	.469	.582	.4	.752	.935
.2	.475	.590	.5	.759	.943
.3	.482	.599	.6	.766	.951
.4	.488	.607	.7	.772	.959
.5	.495	.615	.8	.779	.968
.6	.502	.623	.9	.785	.976
.7	.508	.631	12	.792	.984
.8	.515	.640	.1	.799	.992
.9	.531	.648	.2	.805	1.000
8	.528	.656	.3	.812	1.009
.1	.535	.664	.4	.818	1.017
.2	.541	.672	.5	.825	1.025
.3	.548	.681	.6	.832	1.033
.4	.554	.689	.7	.838	1.041
.5	.561	.697	.8	.845	1.050
.6	.568	.705	.9	.851	1.058
.7	.574	713	13	.858	1.066
.8	.581	.722	.1	.865	1.074
.9	.587	.730	.2	.871	1.032
9	.594	.738	.3	.878	1.091
.1	.601	.746	.4	.884	1.099
.2	.607	.754	.5	.891	1.107
.3	.614	.763	.6	.898	1.115
.4	.620	.771	.7	.904	1.123
.5	.627	.779	.8	.911	1.132
.6	.634	.787	.9	.917	1.140
.7	.640	.795	14	.924	1.148
.8	.647	.804	.1	.931	1.156
.9	.653	.812	.2	.937	1.164
10	.660	.820	.3	.944	1.173
.1	.667	.828	.4	.950	1.181
.2	.673	.836	.5	.957	1.189

TABLE 17—*Continued*

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
14.6	.964	1.197	19	1.254	1.558
.7	.970	1.205	.1	1.261	1.566
.8	.977	1.214	.2	1.267	1.574
.9	.983	1.222	.3	1.274	1.583
15	.990	1.230	.4	1.280	1.591
.1	.997	1.238	.5	1.287	1.599
.2	1.003	1.246	.6	1.294	1.607
.3	1.010	1.255	.7	1.300	1.615
.4	1.016	1.263	.8	1.307	1.624
.5	1.023	1.271	.9	1.313	1.632
.6	1.030	1.279	20	1.320	1.640
.7	1.036	1.287	.1	1.327	1.648
.8	1.043	1.296	.2	1.333	1.656
.9	1.049	1.304	.3	1.340	1.665
16	1.056	1.312	.4	1.346	1.673
.1	1.063	1.320	.5	1.353	1.681
.2	1.069	1.328	.6	1.360	1.689
.3	1.076	1.337	.7	1.366	1.697
.4	1.082	1.345	.8	1.373	1.706
.5	1.089	1.353	.9	1.379	1.714
.6	1.096	1.361	21	1.386	1.722
.7	1.102	1.369	.1	1.393	1.730
.8	1.109	1.378	.2	1.399	1.738
.9	1.115	1.386	.3	1.406	1.746
17	1.122	1.394	.4	1.412	1.754
.1	1.129	1.402	.5	1.419	1.763
.2	1.135	1.410	.6	1.426	1.771
.3	1.142	1.419	.7	1.432	1.778
.4	1.148	1.427	.8	1.439	1.788
.5	1.155	1.435	.9	1.445	1.796
.6	1.162	1.443	22	1.452	1.804
.7	1.168	1.451	.1	1.459	1.812
.8	1.175	1.460	.2	1.465	1.820
.9	1.181	1.468	.3	1.472	1.829
18	1.188	1.476	.4	1.478	1.837
.1	1.195	1.484	.5	1.485	1.845
.2	1.201	1.492	.6	1.492	1.853
.3	1.208	1.501	.7	1.498	1.861
.4	1.214	1.509	.8	1.505	1.869
.5	1.221	1.517	.9	1.511	1.878
.6	1.228	1.525	23	1.518	1.886
.7	1.234	1.533	.1	1.525	1.894
.8	1.241	1.542	.2	1.531	1.902
.9	1.247	1.550	.3	1.538	1.911

TABLE 17—*Continued*

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
23.4	1.544	1.919	27.7	1.828	2.271
.5	1.551	1.927	.8	1.835	2.280
.6	1.558	1.535	.9	1.841	2.288
.7	1.564	1.943	28	1.848	2.296
.8	1.571	1.952	.1	1.855	2.304
.9	1.577	1.960	.2	1.861	2.312
24	1.584	1.968	.3	1.868	2.321
.1	1.591	1.976	.4	1.874	2.329
.2	1.697	1.984	.5	1.881	2.337
.3	1.604	1.993	.6	1.888	2.345
.4	1.610	2.001	.7	1.894	2.353
.5	1.617	2.009	.8	1.901	2.362
.6	1.624	2.017	.9	1.907	2.370
.7	1.630	2.025	29	1.914	2.378
.8	1.637	2.033	.1	1.921	2.386
.9	1.643	2.042	.2	1.927	2.394
25	1.650	2.050	.3	1.934	2.403
.1	1.657	2.058	.4	1.940	2.411
.2	1.663	2.066	.5	1.947	2.419
.3	1.670	2.075	.6	1.954	2.427
.4	1.676	2.083	.7	1.960	2.435
.5	1.683	2.091	.8	1.967	2.443
.6	1.690	2.099	.9	1.973	2.452
.7	1.696	2.107	30	1.980	2.460
.8	1.703	2.116	.1	1.987	2.468
.9	1.709	2.124	.2	1.993	2.476
26	1.716	2.132	.3	2.000	2.485
.1	1.723	2.140	.4	2.006	2.493
.2	1.729	2.148	.5	2.013	2.501
.3	1.736	2.157	.6	2.020	2.509
.4	1.742	2.165	.7	2.026	2.517
.5	1.749	2.173	.8	2.033	2.526
.6	1.756	2.181	.9	2.039	2.534
.7	1.762	2.189	31	2.046	2.542
.8	1.769	2.198	.1	2.053	2.550
.9	1.775	2.206	.2	2.059	2.558
27	1.782	2.214	.3	2.066	2.567
.1	1.789	2.222	.4	2.072	2.575
.2	1.759	2.230	.5	2.079	2.583
.3	1.802	2.239	.6	2.086	2.591
.4	1.808	2.247	.7	2.092	2.599
.5	1.815	2.255	.8	2.099	2.608
.6	1.822	2.263	.9	2.105	2.616

TABLE 17—*Continued*

EQUIVALENT FREIGHT RATES PER GALLON OF OIL IN BULK OR IN WOODEN BARRELS, BASED ON FREIGHT RATES PER HUNDREDWEIGHT

Per cwt.	Bulk per gallon	Wooden barrel per gallon	Per cwt.	Bulk per gallon	Wooden barrel per gallon
32	2.112	2.624	36	2.376	2.952
.1	2.119	2.632	.1	2.383	2.960
.2	2.125	2.640	.2	2.389	2.968
.3	2.132	2.649	.3	2.396	2.977
.4	2.138	2.657	.4	2.402	2.985
.5	2.145	2.665	.5	2.409	2.993
.6	2.152	2.673	.6	2.416	3.001
.7	2.158	2.681	.7	2.422	3.009
.8	2.165	2.690	.8	2.429	3.018
.9	2.171	2.698	.9	2.439	3.026
33	2.178	2.706	37	2.422	3.034
.1	2.185	2.714	.1	2.049	3.042
.2	2.191	2.722	.2	2.455	3.050
.3	2.198	2.731	.3	2.462	3.059
.4	2.204	2.739	.4	2.468	3.067
.5	2.211	2.747	.5	2.475	3.075
.6	2.218	2.755	.6	2.482	3.083
.7	2.234	2.763	.7	2.488	3.091
.8	2.231	2.772	.8	2.495	3.100
.9	2.237	2.780	.9	2.501	3.108
34	2.244	2.788	38	2.508	3.116
.1	2.251	2.796	.1	2.515	3.124
.2	2.257	2.804	.2	2.521	3.132
.3	2.264	2.813	.3	2.528	3.141
.4	2.270	2.821	.4	2.534	3.149
.5	2.277	2.829	.5	2.541	3.157
.6	2.284	2.837	.6	2.547	3.165
.7	2.290	2.845	.7	2.554	3.173
.8	2.297	2.854	.8	2.561	3.182
.9	2.303	2.802	.9	2.567	3.190
35	2.310	2.870	39	2.574	3.198
.1	2.317	2.878	.1	2.581	3.206
.2	2.322	2.886	.2	2.587	3.214
.3	2.330	2.895	.3	2.594	3.223
.4	2.336	2.903	.4	2.600	3.231
.5	2.343	2.911	.5	2.607	3.239
.6	2.350	2.919	.6	2.614	3,247
.7	2.356	2.927	.7	2.620	3.255
.8	2.363	2.936	.8	2.627	3.264
.9	2.369	2.944	40	2.640	3.280

TABLE 18

MISCELLANEOUS PER TON FREIGHT RATES AND EQUIVALENT RATES PER GALLON

Per ton	Bulk per gallon	Wooden barrel per gallon
10	.033	.041
15	.050	.061
20	.066	.082
22½	.074	.092
25	.083	.103
30	.099	.123
35	.116	.144
40	.132	.164
45	.149	.185
50	.165	.205
53	.175	.217
55	.182	.226
60	.198	.246
63	.208	.258
65	.215	.267
70	.231	.287
75	.248	.308
80	.264	.328

BUSINESS LAW IN DAILY USE

The following brief statements pertaining to business law comprise the essence of many pages of legal reading:

1. Ignorance of the law is no excuse.
2. Principals are responsible for the acts of their agents.
3. Checks or drafts must be presented for payment without undue delay.
4. The law compels no one to do impossibilities.
5. Signatures made with lead-pencil are good in law.
6. Contracts made on Sunday are not enforceable.
7. A receipt for money is not conclusive.
8. The acts of one partner bind the other partners.
9. The word "limited," in connection with a firm name, indicates that the responsibility of each of the firm members is fixed.
10. An agreement without valuable consideration is void.
11. It is a fraud to conceal a fraud.

Where one has money [illegible] money

CHAPTER VII

MECHANICAL AND LUBRICATING ENGINEERING DATA

TABLE 19

TOTAL AVERAGE COST OF POWER PER BRAKE HORSE-POWER YEAR (308 DAYS)

(Taken from Lefax Data Sheets to the nearest dollar)

Size of plant	Cost of coal, per ton							
	$2.00		$3.00		$4.00		$5.00	
	Service		Service		Service		Service	
	10 hours	24 hours	10 hours	24 hours	10 hours	24 hours	10 hours	24 hours
100	$61	$96	$71	$116	$81	$136	$91	$156
200	53	83	62	101	71	119	80	137
300	46	74	55	90	63	107	71	123
400	42	67	50	83	58	99	66	115
500	37	59	44	73	51	87	58	101
600	32	51	38	64	44	76	50	88
700	28	45	34	56	39	67	45	78
800	25	40	30	50	35	59	40	69
900	23	36	27	44	31	52	35	61
1000	20	32	24	39	27	46	31	52
1500	18	28	21	34	24	39	27	45
2000	17	26	20	31	22	36	25	40
2500	16	24	18	29	21	33	23	37
3000	15	22	17	26	19	30	21	34
4000	14	21	16	24	18	28	20	31
5000	13	19	15	22	16	25	18	29

NOTE.—In compiling this table, the following factors have been considered in totaling the average costs: Cost of attendance; cost of fuel; cost of oil, waste, etc.; fixed charges, including depreciation, repairs, interest, insurance.

SHAFTING

Classes of Shafting.—There are three general classes of shafting, namely: (*a*) "Jack shafts," which are belted direct to the engine; (*b*) "Line shafting," which is belted direct to the jack shaft, the term being applied to the long lines of shafting used for power transmission; (*c*) "Counter-shafting," which is the shafting that receives its power from the line shafting and transmits it through tight and loose pulleys or friction clutches to the various machines.

Pulley Speeds.—If the diameters of the driving pulley and the driven pulley are known, and it is desired to know the revolutions of the driven pulley, the following formula may be used:

$r = \dfrac{D \times R}{d}$ where R = R. P. M. of driving pulley.
D = Diameter of driving pulley.
d = Diameter of driven pulley.
r = R. P. M. of driven pulley.

Average Shafting Speeds.—The average universal speeds for shafting are as follows:

Woollen mills	300–400 revolutions per minute
Machine shops	125–175 revolutions per minute
Wood working mills	200–250 revolutions per minute
Cotton mills	300–400 revolutions per minute

Approximate Distances Between Bearings for Various-sized Steel Shafts.—

Diameters, inches	Bearing centres, feet and inches
1	6–0
1½	6–6
2	8–6
2½	10–0
3	11–0
3½	12–0
4	13–0

NOTE.—Bearings are generally 8′ 0″ apart.

Hangers.—When a shaft is suspended from the ceiling, the bearing is usually carried in a cast-iron frame, called a " hanger."

A " hanger," when set on the floor, is called a " floor frame," and when fastened to the wall or to a post is called a " post hanger."

Hanger Bearings.—The most important part of a hanger is the bearing. A self-oiling hanger bearing usually contains a ring or chain-feed oiler. Some shafting bearings are lubricated by means of wicking, which feeds oil from a small reservoir. Hangers are usually provided with some method for adjustment, to provide for alignment of the shafting.

Alignment of Shafting.—One of the largest sources of friction loss in a mill is the line shafting. Often the line shafting losses are as high as 25 per cent. or more of the total power delivered by the engine.

Poor lubrication and bad alignment of the shafting are the chief causes of shafting friction losses.

"*Shafting may be placed in proper alignment*" by the following method, which can be used in the field by the lubricating engineer:

Drop a plumb-line from the two end bearings and locate the indicated points with tacks. Run a line between the two tacks with a chalked string.

At intervals along the chalk-mark drive tacks into the floor, just far enough to hold them steady. By means of a straight edge and level, adjust the tacks until the heads are level.

Make a rod, having a length exactly equal to the distance between the first bearing and the first tack.

By turning the shaft and testing it at the various tacks, each of the shaft bearings may be adjusted, until the rod can be made to just reach between the shaft and the tack heads at all points, indicating alignment.

Ball-bearing Shaft Hangers.—Line shaft hangers are sometimes equipped with ball bearings. Such an equipment will usually result in a great saving of power and give satisfactory results.

THREAD CUTTING AND THREAD-CUTTING LUBRICANTS

Both straight mineral oils and mineral lard oils are in general use as lubricants for thread cutting. Soluble oils are also in general use, especially for general thread-cutting work and for drilling, as is later described.

For bolts and nuts a paraffine oil of about 200 Say. Vis. at 100° Fahr. will give satisfactory results.

When soluble oils are used, they are invariably fed by the continuous-feed method, using a circulating system. The used oil is drained to a settling tank and repumped to the feed pipe. When selecting a soluble cutting oil, its properties of separating from metallic dust should be examined, especially when it is to be used for cutting brass.

Mineral lard oils are made with all percentages of lard oil. A very satisfactory mineral lard oil will fill the following specifications:

Baumé gravity	26° to 29°
Open cup flash	Not less than 380° Fahr.
Cold test	Not above 30° Fahr.

To contain not less than 27 per cent., nor more than 30 per cent. lard oil, and not to contain more than 5 per cent. free fatty acid, calculated as oleic acid.

Viscosity about 130° Say. at 100° Fahr.

The oil should show no corrosion on a polished plate immersed in it for a week, and should work equally well unadulterated or when compounded with kerosene or soda water.

A good pipe-cutting oil consists of 75 per cent. red paraffine oil of 415° Fahr. flash test and 225° Say. Vis. at 100° Fahr., compounded with 25 per cent. of whale oil.

Soda Mixtures.—A soda mixture for machine tools in use by a large railroad is made as follows: Dissolve 5 pounds of common sal soda in 40 gallons of water and thoroughly mix it. When ready to use, mix the soda solution with 1 pint of extra No. 1 lard oil and 2 pints of paraffine oil of 24° to 25° gravity Baumé, 300° Fahr. flash, 30° Fahr. cold test.

Another soda mixture which is recommended by some shops is prepared as follows:—

40 gallons of water.
10 gallons of mineral lard oil.
2½ pounds of soda ash (no more or no less).
10 ounces of borax.

The soda ash is weighed (caustic soda or caustic potash will not do), and dissolved with the borax in a bucket of hot water. This is put into a clean tank and thoroughly mixed for thirty minutes and the mineral lard oil then added, when, upon mixing, the solution will form a milky emulsion.

DRILLING

TABLE 20

DRILLING SPEEDS

Diameter of drill, inches	R. P. M., soft steel	R. P. M., brass	R. P. M., cast iron
3/16	600	1200	750
¼	425	900	550
⅜	280	600	360
½	200	425	266
⅝	160	360	213
¾	130	280	172
⅞	120	240	148
15/16	110	230	138
1	95	205	120
1¼	75	165	95
1½	60	140	80
1¾	45	110	68
2	40	100	55

NOTE.—The proper speeds for drilling depend largely upon the material and vary according to the degree of refractoriness of the material drilled. A feed of one inch. in from 95 to 125 R. P. M., is the maximum that should be attempted. At these speeds it will be necessary to use plenty of oil.

Testing the Efficiencies and Economies of Drilling Lubricants.—Soluble cutting oils and cutting compounds are generally used for the lubrication and cooling of drills. These soluble oils are dissolved in varying quantities of water, according to the work to be done.

Some oils selling at a low price per gallon may work satisfactorily only when mixed with water, in the ratio of one to five; while other more efficient soluble oils, which may cost a little more per gallon, will do satisfactory work when mixed in ratios as high as fifteen parts of water to one part of oil, or more.

It is therefore desirable to establish a standard method of comparison for soluble drilling and cutting oils, so that the relative economies and efficiencies of these oils may be determined.

In the following sample test a method of operation is outlined which may be used as a guide, in conducting comparative tests on several soluble oils, and the method of preparing a report on the results of the tests. Assumed conditions are taken as a means of illustration.

ECONOMY TEST SOLUBLE CUTTING AND DRILLING OILS

Object of Test.—To compare the relative economies of three soluble drilling oils costing:—

Oil (*A*).. 33 cents per gallon
Oil (*B*).. 36 cents per gallon
Oil (*C*).. 45 cents per gallon

Operation of Test.—The three oils were emulsified with water in such proportions as to bring the cost of each mixture to a standard price of five cents per gallon, as follows:—

(*A*) $\frac{33}{X+1}=5$ X = Number gallons of water required to make emulsion cost 5 cents per gallon.

$33=5X+5;$ $X(A) = 5\frac{3}{5}$ gallons water.

(*B*) $\frac{36}{X+1}=5$

$\frac{36-5}{5}=X;$ $X(B) = 6\frac{1}{5}$ gallons water.

(*C*) $\frac{45}{X+1}=5;$ $X(C) = 8$ gallons water.

Each of the oils was emulsified with the quantities of water as indicated above and was tested in practical drilling tests as follows:—

TEST NO. 1

Using a one-inch drill and maintaining a constant feed and speed, as well as a minimum feed of emulsion to do the work, six holes were drilled in a steel casting to a depth of one inch, with each of the emulsions.

TEST NO. 2

One hole, using each emulsion, was drilled through a billet of open-hearth steel, using a one-inch drill, running at 150 R. P. M. and fed at a constant feed. (The billet was 4 inches in thickness.)

The following points were noted during each test:—

(*a*) Average temperature of the drill.
(*b*) Average consumption of the emulsions.
(*c*) Condition of the drill on completion of the drilling.
(*d*) Defects or irregularities in the hole drilled.
(*e*) Any overheating or seizing of the drill.

CORROSION TEST

Each emulsion was subjected to a corrosion test. This test consisted in suspending strips of highly polished steel in each of the emulsions and allowing them to remain for a period of two weeks. On removal, the test pieces of steel should show no corrosion upon their polished surfaces.

EMULSION TEST

Small quantities of each of the emulsions were placed in clean glasses and allowed to stand for two weeks in a place where they were not disturbed. Any high percentages of separation were noted.

SUMMARY OF TESTS

Emulsion	Ratio parts water to parts oil		Remarks and condition of drill	
	Test No. 1	Test No. 2	Test No. 1	Test No. 2
Oil (*A*)	5 3/5–1	5 3/5–1	Poor, seizing	Fair, overheating.
Oil (*B*)	6 1/5–1	6 1/5–1	Good, seized slightly	Good, no trouble.
Oil (*C*)	8.0–1	8.0–1	Good, satisfactory, good holes	Very good, no trouble.

NOTE.—By comparing the tabulated results of the tests, it is easy to decide that Oil "C," although costing more per gallon than Oils (A) and (B), is the most economical and satisfactory in service; because it gives the largest and most efficient emulsion, per gallon of oil.

GENERAL SPECIFICATIONS FOR SOLUBLE CUTTING OIL

The oil should be a clear homogeneous mixture. It should consist in liquid form, of soluble alkali soap and mineral oil, or mineral oil compounded with rosin or suitable fixed oils.

It should contain between 20 per cent. and 30 per cent. of soluble alkali soap.

The oil must be free from mineral acids, free alkali, and disagreeable odors.

GRINDING

Grinding Lubrication.—The lubricant used for grinding "lubrication" may lubricate to some degree and reduce the friction of the cutting particles on the wheel, but it also has other important functions, namely:

(*a*) It eliminates the grinding-dust evil, as the lubricant carries away the dust.

(*b*) It keeps the temperature of the work more uniform over the entire surface of the cylinder, by distributing the "cutting heat."

(*c*) It carries away the heat generated by the wheel when cutting particles from the work and thus reduces the power required for grinding.

Grinding Notes.—Originally all grinding was done dry.

As an improvement, first a few drops of water were used, then a small stream was allowed to run on the wheel, and as more work was done, it is now good practice to allow a large stream of lubricating compound to flow on the wheel where it comes into contact with the piece being ground.

Clear water was first used, and then, because of rusting, soda water was substituted. Soda is a lubricant, and an improvement was noticed. Then soapy water and other compounds consisting of oil, soda water, soap, etc., were developed. Perhaps even better results would be obtained from clear oil, if it were more universally used.

When work is ground dry, very light cuts must be taken in order to prevent excessive heat from being generated and causing harm to the work. This heat, due to the slow revolution of the work, will accumulate and produce warping.

It is impossible, under a heavy cut, to grind round and perfect cylinders. Enough grinding compound must be used to dissipate the heat. The term "grinding lubrication" is a misnomer.

HARDENING AND TEMPERING

Steel.—When steel is received in the annealed state, the carbon in it is in the form of "Pearlite" or softening carbon. Pearlite is a formation in steel, that is made up of definite proportions of iron carbide (Cementite) and iron (Ferrite). "Cementite" is a chemical formation of iron and carbon, which consists of approximately 93.3% iron and 6.67% carbon.

"Martensite," or, hardening carbon is the constituent in steel that gives it hardness. By heating steel up to a temperature ranging between 1380° Fahr. and 1480° Fahr., depending upon the amount of carbon in the steel, the "Ferrite and Pearlite" elements are decomposed, forming a new constituent called "Martensite," or, hardening carbon. This hardening carbon can then be trapped in the steel, by quickly cooling it by quenching, and the steel will be hard and brittle.

Hardening.—The process of hardening steel consists in first heating it up to the temperature where hardening carbon is formed, and then cooling it quickly, by means of some form of bath.

When the steel is heated, its temperature is usually brought to a slightly higher point than the exact hardening temperature, because if cooled quickly from some point below the critical temperature, the steel will not have its maximum hardness. The degree of hardness is governed by the rate of cooling, and by the carbon content of the steel. The rate of cooling is dependent upon the size of the piece being hardened, and upon the characteristics of the quenching medium, particularly its quenching speed.

Quenching.—Several quenching mediums are used, but the most important from the standpoint of this book are oil and water.

Quenching oil must have a uniform "quenching speed." It must have sufficient flash to prevent the giving off of large amounts of vapor and it must have a low gumming tendency, with continued use.

The bath used must have a sufficient capacity to allow the free circulation of the oil, in order that the temperature of the bath may be kept uniform. Oil quenching does not produce as great a shock to the steel as does quenching in water. When a very hard piece is desired, water covered with a few inches of oil may be used.

When putting a piece in the tank, it should never be thrown in and allowed to lie on the bottom of the tank, because the side exposed to the

oil will cool faster than the other side and warping will occur. If the piece is thin in one part and thick in another, the thick parts should be allowed to come into contact with quenching medium first. In order that the liquid may cover the maximum amount of surface in the shortest time, the piece should be put into the bath in the direction of its axis of symmetry. For instance, when hardening a gear, put it into the bath in a direction perpendicular to its plane, and when hardening a shaft put it in, in a direction at right angles to its axis.

In order that a film of vapor will not collect over the surfaces of the piece, which would retard the evenness of the cooling, the piece should be moved about. Thin pieces should always be oil quenched to prevent warping and cracking.

Tempering.—The operation known as tempering consists in reheating steel that has been hardened, to some temperature that is between the normal air temperature and the temperature at which the steel was quenched. Some of the softening carbon will then be formed. Steel that has been hardened is usually too hard and brittle for use, until it has been tempered. Tempering is usually carried on in baths of heated oil, molten salt or lead drawing furnaces. For heavy tempering, such as car springs, wagon springs, etc., an oil with a high flashing point, such as a petroleum cylinder stock is recommended. A suitable oil for this purpose will have the following general tests:—

Gravity	25° B.	Viscosity	about 180 @ 212° Fahr.
Flash	600° Fahr.	Dark.	
Cold test	28° Fahr.		

For light work and small parts a lighter oil should be used. A typical oil would have the following general tests:—

(A)		(B)	
Flash	375–400° Fahr.	Flash	400–420° Fahr.
Viscosity	130 @ 100° Fahr.	Viscosity	280–295 @ 100° Fahr.
Cold test	25– 30° Fahr.	Cold test	25– 30° Fahr.

NOTE.—Oil (A) is for very light work, and oil (B) is for use with heavier work.

Quenching in oil does not chill the piece as does quenching in water, because the fumes of oil that surround the piece are higher in temperature than the temperature of steam. Oil tempered steel is more elastic. For instance, the heavy oil listed above, flashes at 600° Fahr. and if the piece is covered with the oil and the oil is burned off, the resulting temperature

will be practically 600° Fahr. The bath of oil is sometimes heated to an exact temperature, to draw the temper of a series of pieces the same.

For a description of the use of oil coolers to cool the oil used in tempering baths, see the Appendix at the back.

WORK AND POWER

Work is the product of force and space. The unit of work is the foot-pound. The foot-pound may be defined as the amount of work done, when a pound weight is raised through a distance of one foot, against the forces of gravity.

Power.—Power is the rate of doing work.

Horse-power.—Mechanical power is measured by the horse-power. A horse-power is defined as being that rate of doing work, which would lift a pound weight 33,000 feet per minute, or 33,000 pounds one foot per minute.

British Thermal Unit.—A British Thermal Unit, which is usually referred to as a B. T. U., is the mechanical equivalent of heat. One B. T. U. equals 778 foot-pounds.

To change English horse-power to B. T. U. per minute, use the following formula:—

$$\text{B. T. U. per minute} = \frac{\text{Horsepower} \times 33000}{778}$$

$$\text{One horsepower} = \frac{33000}{778} = 42.4 \text{ B. T. U. per minute.}$$

CHAPTER VIII

STEAM ENGINES AND STEAM TURBINES

SLIDE-VALVE STEAM ENGINES

THE cylinder valves of slide-valve steam engines, may be plane blocks sliding back and forth upon plane seats, or the valve seat may be a segment of a cylinder or a cone, which fits a corresponding surface of the valve, steam tight.

Fig. 24 shows a sectional view of a plain, slide-valve engine cylinder and valve chest.

It is the function of the valve to time the events: admission, cut-off, release, and compression. The valve shown in Fig. 25 is the ordinary

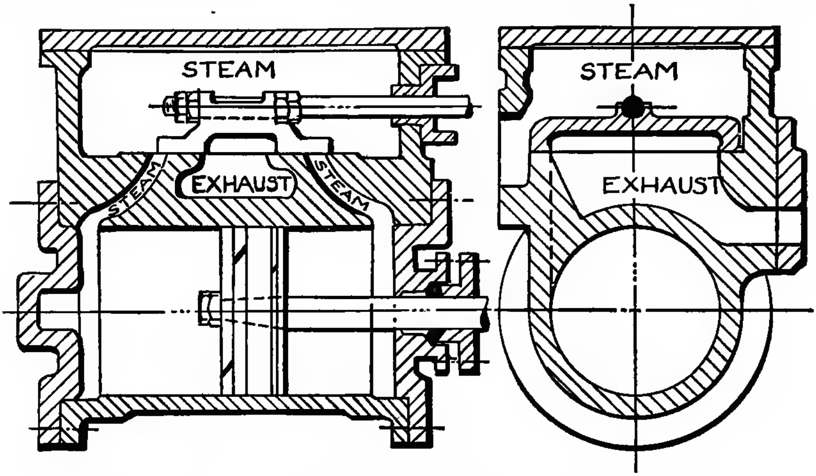


FIG. 24.—Sectional view of plain slide-valve engine, showing the cylinder and valve chest.

D slide valve. The cut shows its appearance when looking up at it from the position of the valve seat. The flat surfaces, which rub upon the valve seat are clearly shown.

The valve derives its motion from the "crank shaft," through the medium of the "eccentric," "eccentric rod," and "valve stem." The part of the eccentric, which revolves with the shaft is called the "eccentric sheave," and the bands which are about the eccentric sheave are called the "eccentric straps." The eccentric straps are fastened to the eccentric

rod, whose motion is similar to that of the connecting rod. The rotary motion of the eccentric is transferred into reciprocating motion at the pin *A* (see Fig. 26). The pin *A* is fastened to a "slider," which works in guides and transfers the motion to the valve stem.

The various parts of the simple valve gear for a plain, slide-valve engine are indicated in Fig. 26.

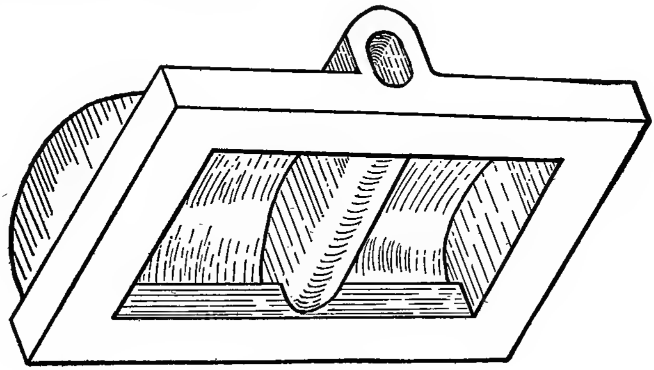


FIG. 25.—Plain "D" slide valve.

CORLISS VALVE ENGINES

Instead of moving back and forth in a straight line, as the ordinary slide valve does, Corliss engine valves move in an angular direction about their axes.

Corliss steam valves are shaped as shown in Fig. 27. There are four valves in each engine—two steam valves and two exhaust valves. The valves extend clear across the cylinder, and are carried in "holes" or valve

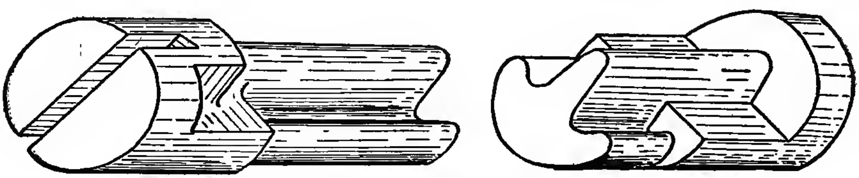


FIG. 27.—Corliss steam valve.

seats, which are bored from side to side through the cylinder. These "holes" are closed at the back by plates and at the front by castings, called "bonnets." At each end of the valves a short portion is made cylindrical, to act as a bearing for the valve.

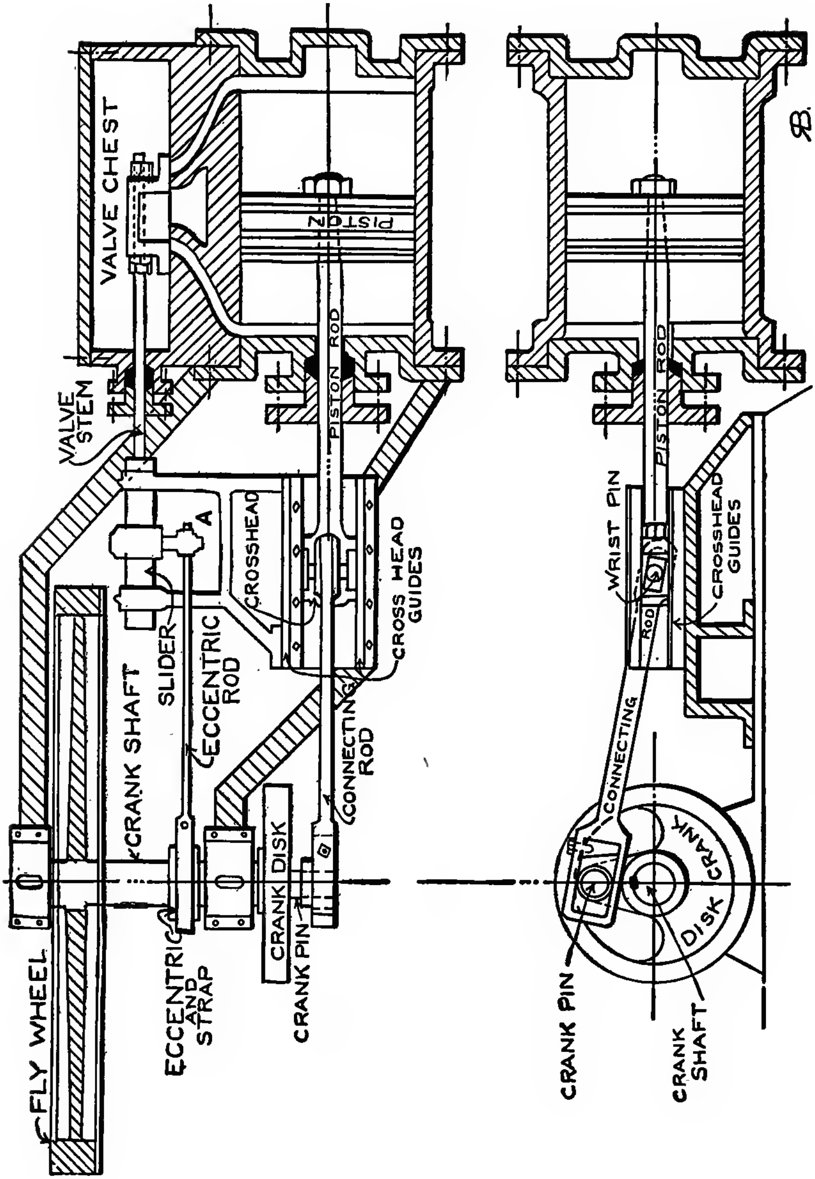


FIG. 26.—Valve gear of simple slide-valve engine.

Fig. 28 shows a sectional view of a Corliss engine cylinder and valves. The valve receives its rocking motion from a " valve spindle," which is equipped with a bearing and a stuffing box in the " valve bonnet." The valve spindles terminate in tongues, which fit into slots across the end of the valves.

Fig. 29 shows the arrangement of the valve gear. A casting called the " wrist plate " oscillates on an axis. The " wrist plate " is kept in motion by the " eccentric " on the main shaft, through the " eccentric rod," or " carrier," and the " reach rod."

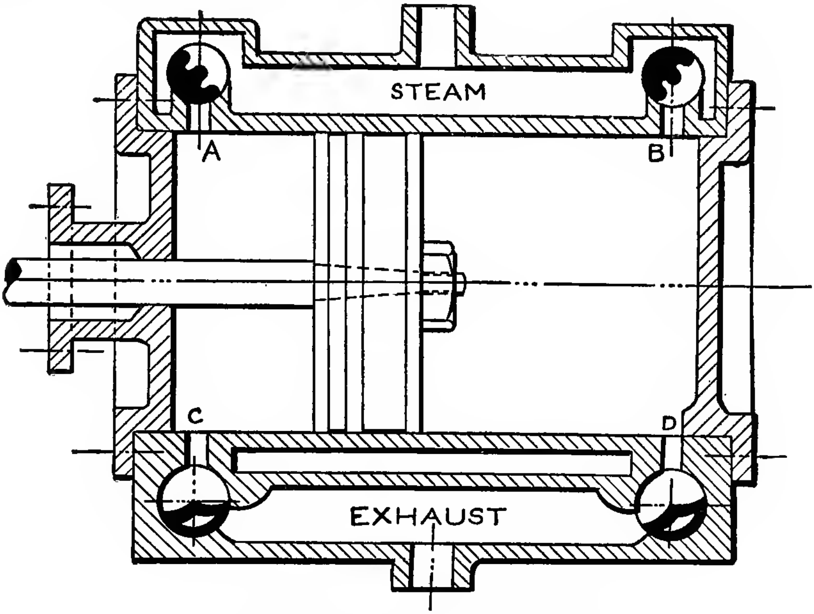


FIG. 28.—Section through Corliss engine cylinder.

Short cranks or exhaust arms are keyed to the stems of the exhaust valves, and are connected to the wrist plate by " exhaust links."

The exhaust valves are in motion all the time.

Each valve, as is shown, is a portion of a cylindrical surface. These valves are oscillated or rocked about their axes, to open and close the ports. *A* and *B* are steam ports, and *C* and *D* are exhaust ports (Fig. 28).

The steam valves are oscillated by the wrist plate, through the medium of the " steam links." The steam links are not directly connected to the valves, as in the case of the exhaust links, but are connected through

special releasing devices. The releasing devices pull the steam valves open at the proper time and then suddenly let go, and the valves are quickly pulled shut by means of the " dash pot rods " and " dash pots."

" Dash pots " are simply pistons, working in cylinders, which have one end closed. As the pistons are pulled up, during the opening of the steam valves, by the rods connecting them to the " releasing gear," a partial vacuum is formed under the pistons, which quickly pulls the rods down and the steam valves closed on release.

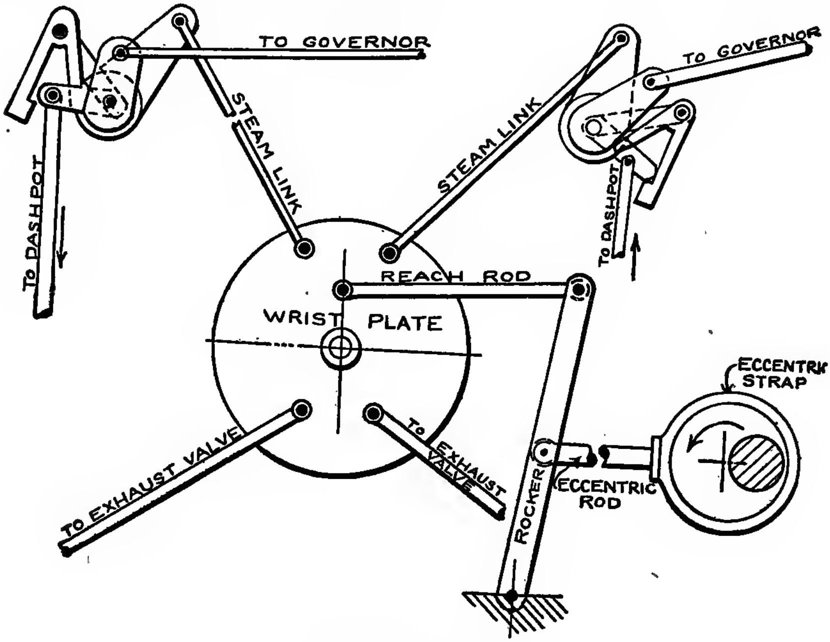


FIG. 29.—Corliss valve gear.

PISTON VALVE ENGINES

A " piston valve " is a slide valve, but differs from the plain type of slide valve, in that, instead of sliding on a plane surface, the valve and valve seat are cylindrical. The " ports " are spread out around the valve, so that steam is admitted or exhausted practically around the entire valve. Fig. 30 shows a simple form of piston valve.

Balanced Valves.—A plain " D slide valve " has the full force of the steam pressure on its outer surface, while its inner surfaces are either in contact with the seat or are subjected only to exhaust pressure. The

result is an unbalanced pressure, producing a heavy friction load upon the valve gear. Piston valves relieve this condition by keeping constant the pressure all about their circumference.

Leakage is usually greater with the piston valve than the plain slide valve, because of the tendency of the former to wear a non-cylindrical seat.

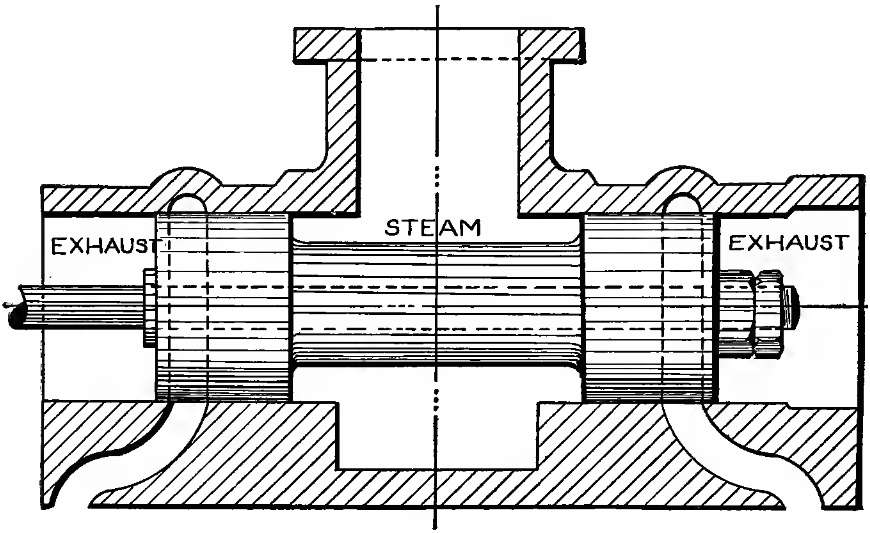


FIG. 30.—Piston valve.

COMPOUND AND TRIPLE EXPANSION ENGINES

The steam may either do all of its work in one cylinder, entering, with the exception of the line loss at boiler pressure and expanding to the exhaust pressure, or it may do part of its work in one cylinder, then exhaust to a second cylinder and do more work, and the process proceed further by exhausting into a third cylinder, etc.

"Simple engines" are those in which the steam expands in one cylinder. "Compound engines" are those in which a second cylinder is supplied with the exhaust of the first, or high-pressure, cylinder.

In a "Cross Compound engine" the high- and low-pressure cylinders are side by side, and each has its own crank on the shaft.

"Tandem Compound" engines are those in which the high- and low-pressure cylinders are in line, both of their pistons being fixed to the same piston rod.

"Angle Compound engines" have their high-pressure cylinder horizontal and their low-pressure cylinder vertical.

"A Triple Expansion engine" allows the steam to expand consecutively in high-pressure, intermediate-pressure, and low-pressure cylinders.

CONDENSING AND NON-CONDENSING ENGINES

When an engine exhausts directly into a "hot well" or to the atmosphere it is said to be running "non-condensing."

When an engine exhausts into a closed vessel, in which a partial vacuum is maintained, and the steam is condensed by means of cold water, the engine is said to be running condensing. The closed vessel is called the "condenser." The condensed steam is used as feed water for the boiler.

THE STEAM TURBINE

The steam turbine generally consists of a disk or a cylinder on the circumference of which are a large number of buckets or blades.

Steam is directed at a definite angle against these buckets and causes the disk or cylinder to revolve at high speeds.

There are a number of commercial types of steam turbines on the market, the principal ones being the Westinghouse, Parsons, DeLaval, Curtis, Terry, etc.

DeLaval Turbines.—In this type of turbine, steam enters a chamber surrounding the casing of the turbine, and is directed by several nozzles to the turbine buckets. These buckets are fastened to the outer circumference of a single disk. The steam is directed against the centre line of the buckets at a small angle. The nozzles are tapered, with the large end toward the bucket, so that the expanding steam acquires a high velocity, which it converts into energy, by causing the bucket disks to rotate. The revolutions per minute of this type of turbine are high (often 30,000 R. P. M.). The tendency of the rotating element is to rotate about its gravity axis instead of its geometric, or mechanical, axis. Provision is made to allow the rotating element to adjust its centre of rotation to its centre of gravity. This is accomplished by pumping oil under pressure into the bearings, as a means of providing an elastic cushion.

Curtis Turbines.—The Curtis type of steam turbine is an impulse turbine; *i.e.,* the rotating element is actuated by the impact of the steam passing through its buckets, at relatively high velocity, but without actual

expansion in them. Comparatively high initial velocity is given to the steam jet by expansion in a nozzle or set of nozzles. This velocity is absorbed as energy by successive action upon a series of alternately movable and stationary vanes. The steam passes through the buckets of any one "stage" by virtue of its velocity only, there being no expansion in the stage. The expansion is accomplished in the nozzle passages

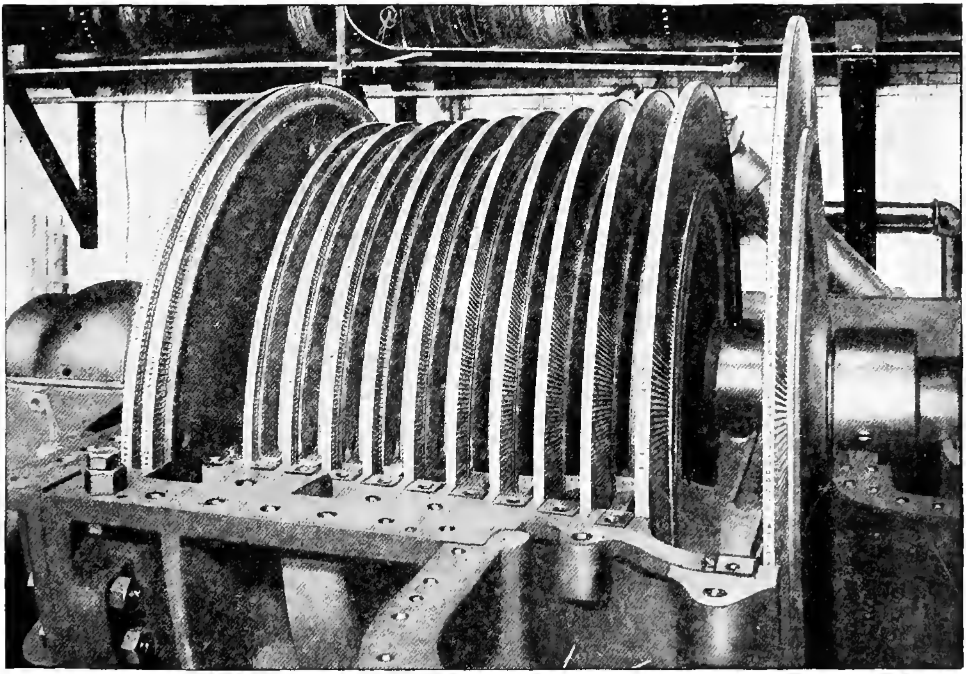


FIG. 31.—Twelve-stage Curtis steam turbine, with the upper half of the turbine casing removed.

between the stages. In other words, when the velocity due to the steam expansion in the original nozzles has been absorbed, it is again generated by further expansion in another set of nozzles, whose area is sufficiently greater than the first, to allow for the increase in volume by the previous expansion. This operation is repeated upon another larger set of vanes, etc.

Fig. 31 shows a twelve-stage Curtis turbine, with the upper half of the turbine casing removed, giving a clear view of the interior construction.

For use in driving ship propellers, pumps, direct-current generators

requiring large turbines, it is necessary to reduce the shaft speed by means of gears. The gears used with the Curtis machine are flexible. They consist of a double gear built up of flexible plates and so constructed that if excessive tooth-pressure is exerted by the pinion teeth at any point, a slight axial flexure in the disks will immediately relieve the excessive pressure.

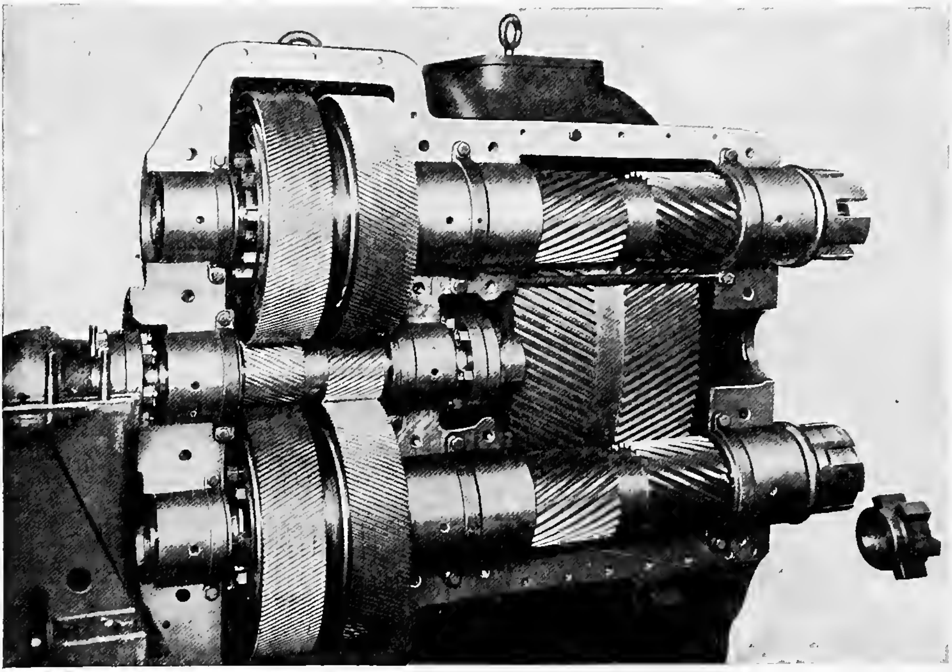


FIG. 32.—1750 horse-power, 3200/137 revolutions per minute, double reduction gear, made by the General Electric Company.

A Curtis double-reduction gear, 1750 horse-power, 3200/137 R. P. M., is shown in Fig. 32.

Westinghouse Turbines.—The original single-flow Parsons type of turbine has been complemented by three Westinghouse variations. The various types are:—

(*a*) Single-flow.

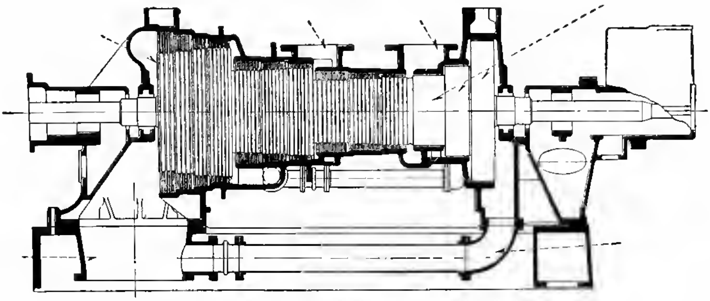
(*b*) Semi-double-flow type.

(*c*) Double-flow type.

(*d*) Impulse and reaction single-flow type.

The names of these types are descriptive of their operation.

Fig. 33 illustrates the original single-flow Parsons type of steam turbine. The steam enters the annular ring chamber in the casing and passes alternately through rings of fixed and moving blades. The length of these blades increases progressively, permitting expansion as the steam passes through the successive rings of blades. When the volume of the steam



Westinghouse Electric and Manufacturing Company

FIG. 33.—Section of a Parsons type single-flow turbine.

has increased to the extent that the blades on the small diameter of drum would have to be made too long, the diameters of the drum and casing are increased for the next stage of expansion.

Fig. 34 illustrates a single-flow rotor from a Westinghouse-Parsons turbine.

FIG. 34.—Single-flow rotor, Westinghouse-Parsons turbine.

For large turbines an oil relay mechanism, as shown in Fig. 35, is used to operate the steam valves. The lubricating oil circulating pump maintains a higher pressure than is required for the lubricating system. The governor controls a small relay valve *A*, which allows the high-pressure oil to flow to, or exhaust from, the operating cylinder.

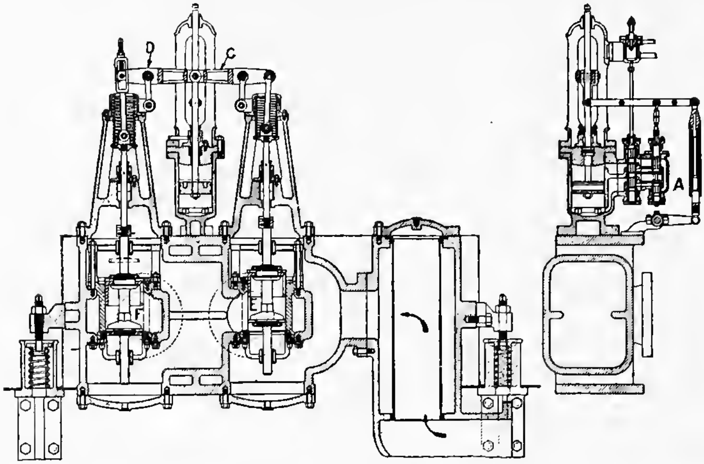


FIG. 35.—Valve gear with oil relay, Westinghouse turbine.

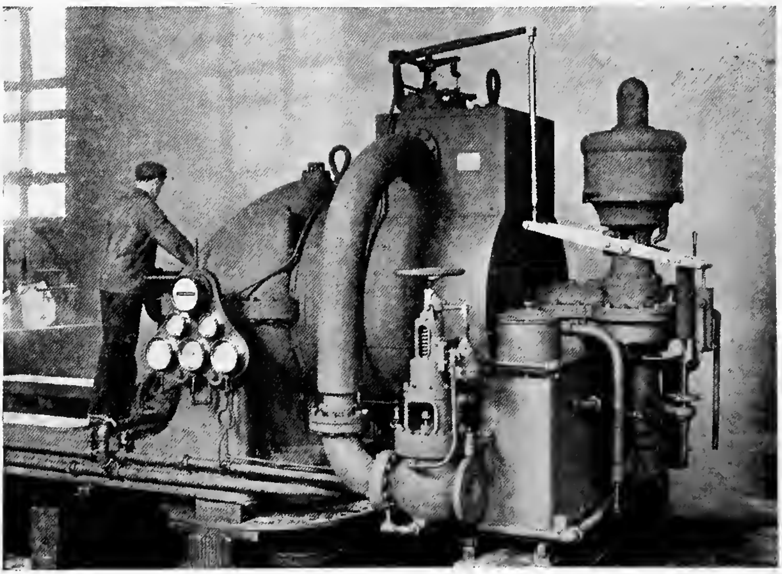


FIG. 36.—Latest design of Westinghouse turbine.

When oil is admitted to the operating cylinder, the lever *D* moves simultaneously with *C,* but, on account of the slotted connection with the stem of the secondary valve *F,* the latter does not begin to move until the primary valve is raised to the point at which effective opening ceases to be increased by further upward travel.

Fig. 36 shows the latest design of Westinghouse turbine, which embodies a combination of the impulse and Parsons types.

Fig. 37 shows the rotor of this machine.

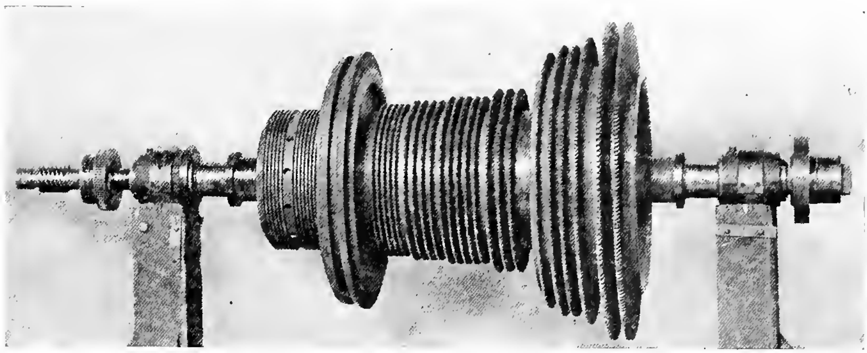


FIG. 37.—Rotor of machine in Fig. 36.

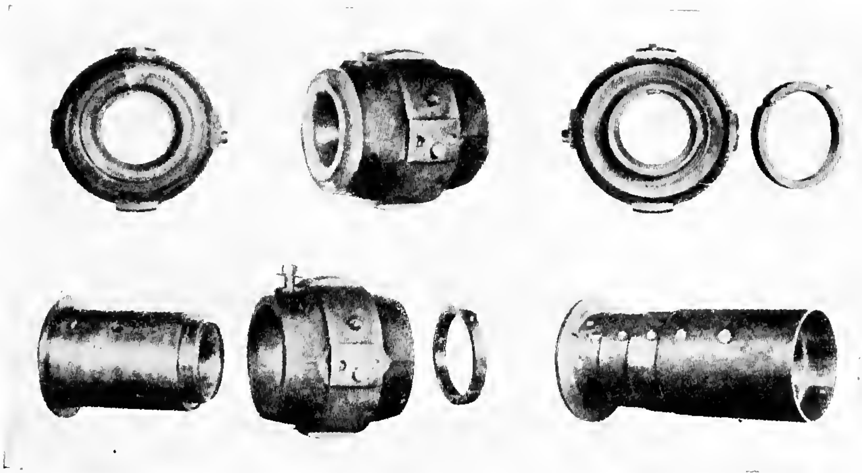


FIG. 38.—High-speed Westinghouse turbine bearing.

High-speed Bearings.—The speed of the spindle, running at more than 3000 R. M. P., tends to rotate it on its gravity axis instead of its geometric, or mechanical axis. This condition might cause disagreeable vibration when the turbine revolves at full speed. To compensate this condition, the Westinghouse Machine Company uses a bearing on high-speed turbines made up of several concentric tubes, having a slight

clearance between them. The lubricating oil fills these clearances with an elastic cushion, which makes the bearing flexible.

The tubes are carried in a cast-iron sleeve which rests upon a pedestal. Fig. 38 shows the various parts and the assembled bearing. There are no water-cooled bearings used on the Westinghouse turbo generators.

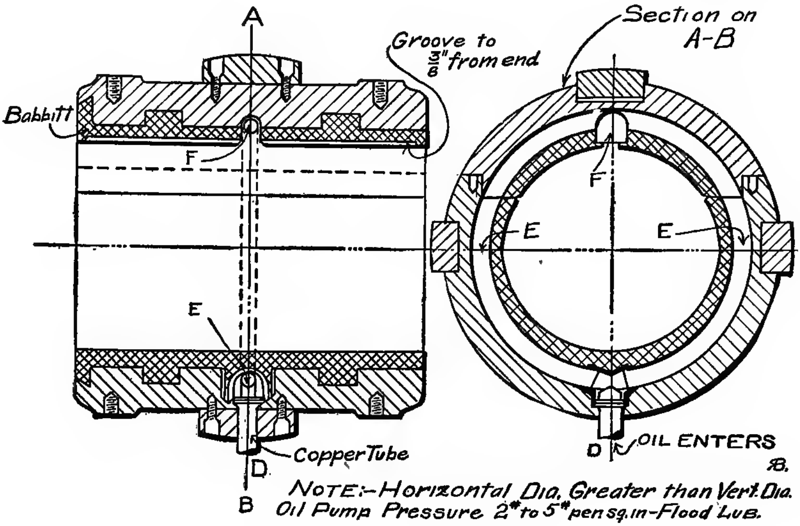


FIG. 39.—Low-speed turbine bearing.

Fig. 39 shows a form of bearing used for low-speed turbine bearings, where the critical speed is never reached, and there is no need for the concentric ring bearings. A Babbitt metal lining is used, and the bearing is made in halves. Before the Babbitt metal is run in, a copper tube *E* is placed in a groove in the shell. The lubricating oil enters at *D* and flows to the top of the bearing through *E* and out through *F*. The groove in the Babbitt surface distributes the oil toward the ends of the bearing.

CHAPTER IX

ELECTRICAL DATA

ENGINEERING

THERE are two classes of electricity; namely, static and dynamic. Dynamic electricity serves useful purposes, such as running motors, lighting, etc., while static electricity is of little practical value.

Analogies to Water.—There are various analogies between the flow of water and electricity, which will serve to illustrate the various electrical terms, as follows:—

WATER	ELECTRICITY
"Head," difference of level, in feet. Pressure, difference in pounds per square inch.	"Difference of potential," measured in volts.
"Resistance" to flow in pipes increases with length, roughness, and decrease in cross-section. Decreases as the sectional area increases.	"Resistance," measured in ohms. It increases directly as the length of the conductor, and decreases as the sectional area increases.
"Rate of flow," measured in cubic feet per second or gallons per minute.	"Current," measured in ampères.
"Power" is rate of work. Rate of flow in cubic feet per second times the head in feet, times the weight of a cubic foot of water, equals the power in foot-pounds per second.	"Power," measured by the watt.

Definitions.—"Electrical resistance" is measured in "ohms." An "*ohm*" is the resistance offered by a uniform column of mercury, 106.3 centimetres in length and 14.4521 grammes in mass, at the temperature of melting ice, to the passage of an electric current.

"Current" is measured in "ampères." An *ampère* is defined arbitrarily by the electrolytic method. For practical purposes it may be defined as the current that will flow through a resistance of one ohm under a pressure of one volt.

Difference of potential is measured by the "*volt*." One volt is equal to the difference of potential, which will cause a current of one ampère to flow through a resistance of one ohm.

Ohm's Law.—One of the most important electrical laws is Ohm's

Law. Briefly it may be stated as follows: Current is directly proportional to the voltage and inversely proportional to the resistance.

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} \text{ (or) Voltage} = \text{Resistance} \times \text{Current.}$$

Therefore, knowing two of the above values, the third can be easily determined.

The Simple Dynamo.—An electrical dynamo is a machine to convert mechanical power into electrical energy.

A dynamo consists of two principal parts; namely: The field magnets and the armature.

If a coil of wire is rotated in a magnetic field, a current will be produced in the coil of wire. This current will flow in one direction for half a revolution, and in the opposite direction for the other half of the revolution. This pulsating current is called "alternating current."

The magnetic field may be produced by permanent magnets or by electro-magnets. A dynamo may have a number of magnets arranged around a circumference, within which a number of coils of wire, suitably joined together and called the armature, rotate. The current collected in the different coils is collected and brought out to the collecting rings.

If "direct current" is desired, the ends of the different coils are brought out to a segmented ring, called the "commutator." A direct current does not pulsate, but flows in one direction. The ends of each coil have their own segments, which are insulated from the segments of the others coils. Brushes, which are in contact with the segments, only as long as the current being generated in that coil is flowing in the desired direction, collect the current from the commutator.

The magnets are called "poles." They may be excited by a small part of the current generated by the dynamo itself, or they may be excited by a separate machine.

There are three kinds of self-excited generators, namely:

(*a*) "Shunt machines," in which only a small part of the current being generated by the dynamo passes through the field coils; that is, the field coil current is "shunted" around the main current.

(*b*) "Series machines," in which all of the current delivered by the armature is passed through the field coils; that is, the coils are in series with the armature.

(*c*) "Compound" machines, which have two coils on each pole. One

coil is a series coil and the other is a shunted coil. This is the common type of generator.

Electric Motors.—The electric motor is the reverse of the electric generator. The current is sent through the armature, which is thus caused to revolve in the magnetic field.

Electrical Measurements.—"Voltage" is measured by the "voltmeter." Current is measured by the "ammeter." These instruments are really small motors that are not allowed to rotate, but turn against the action of a spring, carrying a pointer over a calibrated scale.

Transformers.—The office of a transformer is to change the voltage of an alternating circuit from one value to another, or to change the system from one phase to another.

The transformer consists of two separate coils of wire, insulated from each other and wound upon the same iron core. One of the coils receives alternating current at a high or low voltage, and the other coil supplies current at a low or high voltage respectively. When the transformer receives current at a high voltage, and delivers it at a low voltage, it is called a "step-down transformer." For the reverse conditions, the transformer is called a "step-up transformer."

The receiving coil is called the "primary coil," and the delivery coil is called the "secondary coil." There is always heat produced by the energy losses which occur in the core and the copper wiring in a transformer. It is therefore necessary to provide means for cooling the transformer. There are a number of methods of accomplishing this, namely:

(*a*) Self-cooling up to 15,000 volts.
(*b*) Self-cooling, oil filled up to 80,000 volts.
(*c*) Cooled by air blast.
(*d*) Cooled by water.
(*e*) Cooled by water and oil.

Self-cooling by oil is the general method. The transformer is enclosed in a sheet-iron or steel case, which is filled with oil. The natural circulation of the oil carries the heat from the transformer proper to the casing, which is usually corrugated and from which the heat is radiated. In some cases the oil is circulated by a pump. Water is sometimes passed about the casing to cool the oil. Thin transformer cases should be avoided, since, in case of accident, they may be punctured and spring a leak, causing a loss of oil and possibly a fire.

For transformer oils and practical conditions see Appendix.

PART III

CHAPTER X

BEARING LUBRICATION

ROLLING AND SLIDING FRICTION AND ITS APPLICATION TO BEARINGS

Definition of Bearings.—Bearings are surfaces, or, points of contact, between the frame of a machine and the moving parts. They support and guide the rotating, sliding, or revolving parts, which are called journals, pins, spindles, and shafts.

All bearings may be classed in two main divisions, depending upon the way they carry the load. If the load is carried at right angles to the

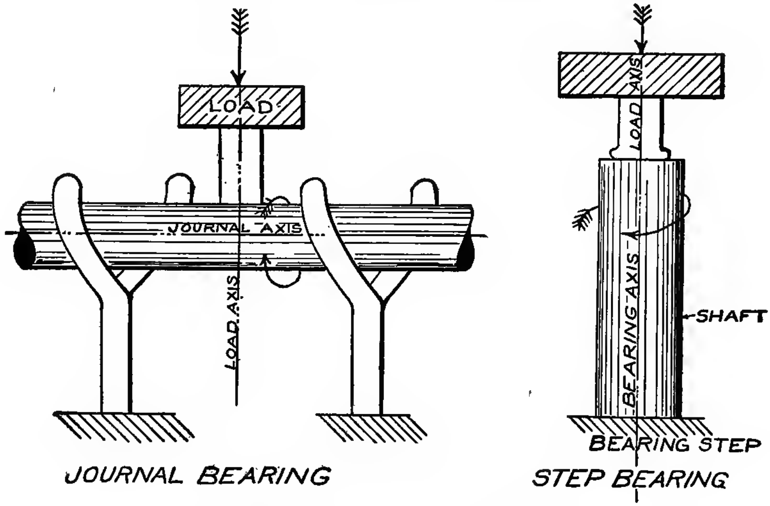


FIG. 40.—Journal and Step Bearings.

axis of the bearing, the bearing is called a " journal bearing " (see Fig. 40). If the load acts in a line parallel to the axis of the bearing, the bearing is called a " thrust bearing," or, a " step bearing."

Journal and step bearings may have either sliding or rolling contact with the moving parts. Rolling contact bearings are equipped with either ball, or roller bearings.

Bearings with Sliding Contact.—Bearings, which permit the moving

parts to slide over them, are called "sliding contact" bearings. There are two main types of these bearings, *i.e.,* step and journal.

Journal Bearings.—A typical journal bearing is shown in Fig. 41. This type of bearing is in most general use and is the oldest type. It has many refinements in design to provide efficient methods of distribution

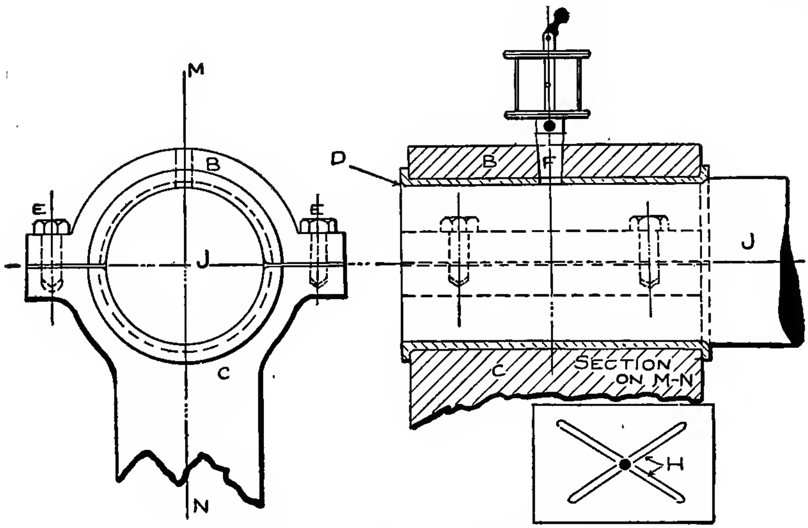


FIG. 41.—Journal bearing with sliding contact.

for the lubricant. The names of the main parts of this type of bearing are given as follows, with letters referring to the figure:—

B—Bearing cap.
C—Bearing.
D—Bearing lining metal.
E—Bearing cap bolts.
J—Journal.
F—Oil-feed hole.
H—Oil grooves, which are chipped in the surface of the bearing metal to improve the distribution of the lubricant.

Step Bearings (Sliding Contact).—A simple type of sliding contact step bearing is shown in Fig. 42. The parts of the bearing, as indicated by the letters in the figure, are given as follows:—

J—Shaft.
B—Lower step bearing.
A—Upper step bearing.
X—Key, for holding the block in rotation with the shaft.
K—Casing, or bearing box.
R—Oil reservoir to allow the bearing to run in a bath of oil.

This type of bearing is in use for both low and high speeds, and is usually equipped with refinements for adjustments and oiling.

Bearing Metals.—Journal bearings, and sometimes step bearings, are lined with various bearing metals, which are different in nature from the metal composing the revolving or rotating parts which they support. It has been found that there is less friction between dissimilar metals in sliding contact than between like metals. For this reason bearing metal is usually different from that composing the rotating part. (This is excepted for hardened steel journals and bearings.) Another reason for

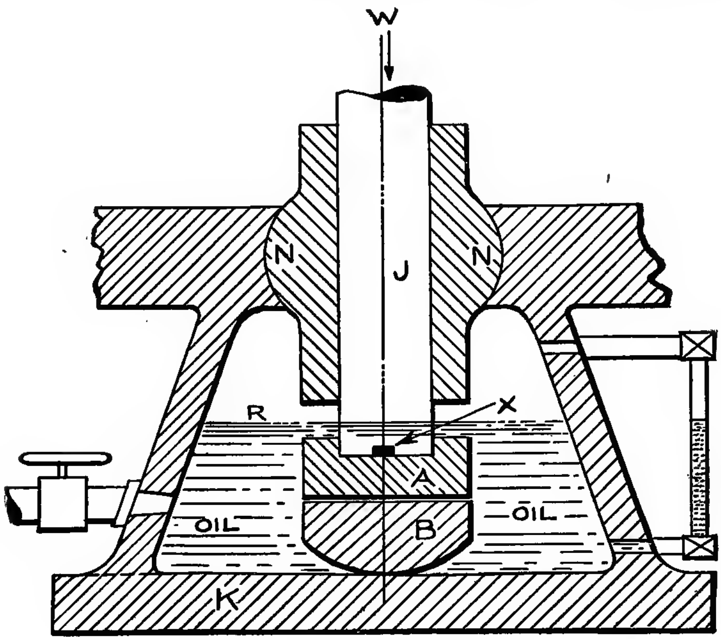


Fig. 42.—Step bearing with sliding contact.

using bearing metal is to provide a quick and easy method of replacing a worn-out bearing by inserting new bearing metal. If the frames of the machine and the journals ran in contact, the wear would be excessive, and when the bearing became worn it would be difficult and expensive to renew it.

Bearing metals are usually Babbitt metal, phosphor bronze, gun metal, manganese bronze, or brass.

Dr. C. D. Dudley, late chemist of the Pennsylvania Railroad, gave the following requirements and characteristics of a good bearing metal:—

(*a*) It must have strength to carry the load without distortion.

(*b*) It must not heat rapidly.

(*c*) It must work well in the foundry. Oxidation causes spongy casting.

(*d*) It must have a low coefficient of friction.

(*e*) It must have a long wearing life.

Babbitt Metal.—The most generally used bearing metal for journal bearings is Babbitt metal, used with soft steel journals. The original Babbitt formula seems to have been: 89.3 per cent. tin, 3.6 per cent. copper, and 7.1 per cent. antimony. The tin gives the required toughness and hardness, the copper gives the strength, and the antimony tends to make the alloy hard and brittle. Babbitt metal is a soft and fusible metal. It has special advantages over the hard bearing metals, due to the cheapness and ease with which a perfect bearing, in line with the shaft, may be made. Another advantage is the ease of renewal of a bearing with Babbitt metal, it being melted and poured into place. Like other fusible bearing metals, Babbitt in a melted state is run into the bearing box or shell, which is part of the machine frame, and into the bearing cap. The journal box holds the Babbitt in shape about the journal.

There are many brands of Babbitt metal on the market; some are good and some are worse than worthless. Ordinary Babbitt metal varies greatly in composition, and often an unreliable dealer supplies refuse type metal for this purpose. The purchaser should buy only from reputable dealers, according to a definite formula, which has been found satisfactory for his use.

An approximate analysis of the various bearing metals in general use is given in Table 21.

TABLE 21

APPROXIMATE ANALYSIS OF VARIOUS BEARING METALS

Babbitt (light duty)	....	89.3	1.8	8.9	....
Hard Babbitt (heavy duty)	....	88.9	3.7	7.4	....
White metal	....	85.0	5.0	1.0	....
White metal No. 2	87.92	...	....	12.08	....
Manganese bronze	....	9.58	90.42	....	....
Gun metal	....	8.25	89.50	....	2.75
Yellow brass	2.0	...	62.3	....	32.70

Lead.—This is one of the most satisfactory bearing metals from an anti-friction standpoint, due to its soft yielding properties. Lead alone,

however, is impractical for use in a bearing as a bearing metal, because it possesses no hardness or toughness. Therefore it must be combined with some other metal to stiffen it.

Cast Iron.—In some bearings cast iron is used as a bearing metal. It must be a good grade of close-grained metal. Due to its granular nature, it seems to have the property of holding the lubricant in place. It is very brittle, however, and will not stand severe shocks without cracking.

Other Bearing Metals.—While soft bearing metals, such as Babbitt, etc., are very generally used, there are certain classes of machinery which require a bearing metal having great toughness, hardness, and heat-resisting qualities. Railroads and rolling mills are particularly hard on bearings. In rolling mills, high temperatures and pressures are encountered, and only the hardest and toughest metals will stand the imposed conditions. Ordinary Babbitt metal would soon be melted and run from the bearings. For railroad bearing requirements brass is largely used. Often the "brasses" are equipped with a crown of soft metal, set as a strip in the brass at the point of greatest pressure and wear. The soft metal takes up the wear, while the brasses give the required strength to the bearing.

Bearing Clearance.—Bearings may be adjusted for a "running clearance" (that is, clearance enough to allow for smooth running, with the bearings and journal at normal running temperature), or they may be given enough clearance, so that should they run hot from any cause, the expansion of the journals and bearings will not be sufficient to cause them to grip and bind. Since pounding frequently accompanies "expansion clearance," it is usual practice to adjust for running clearance only.

Bearing Pressures.—Some approximate pressures per unit area of bearings designed for various purposes may be obtained from the following table. When considering the lubrication requirements of any of the following named bearings, the maximum pressures should be used, in order to provide a good margin of safety.

TABLE 22

ALLOWABLE PRESSURE PER SQUARE INCH FOR VARIOUS BEARINGS AS INDICATED

U. S. Navy:	
Main engine bearings	275–400 pounds per square inch
Main engine crank-pin bearings	400–500 pounds per square inch
Steam turbine bearings	85 pounds per square inch
Thrust bearings	50 pounds per square inch

Merchant Marine:

Main engine bearings	400–500 pounds per square inch
Main engine crank-pin bearings	400–500 pounds per square inch

Slow-speed Stationary Engine:

Main bearing (dead load)	80– 140 pounds per square inch
Main bearing (steam load)	200– 400 pounds per square inch
Crank-pin bearings	800–1300 pounds per square inch
Cross-head pin bearings	1000–1500 pounds per square inch

High-speed Stationary Engine:

Main bearings (dead load)	60– 120 pounds per square inch
Main bearings (steam load)	150– 250 pounds per square inch
Crank-pin bearings (overhung crank)	900–1500 pounds per square inch
Crank-pin bearings (centre crank)	400– 600 pounds per square inch
Cross-head pin bearings	1000–1800 pounds per square inch

Oil Grooves.—Oil grooves are cut into the surface metal of bearings to improve the distribution and efficiency of the bearing lubricant. It has been the general custom in the past to cut oil grooves in both the top and bottom sections of the bearings, but experience has indicated that better results can be obtained by cutting the grooves in the upper half of the bearing only. Nothing should interfere with the suction of the oil from the low-pressure area to the area of high pressure, and it is a law of fluid friction that the friction between a solid and a fluid is increased with an increase in the roughness of the solid surface. For this reason, the "pull" of the journal surface, due to the adhesive effect between the oil and the journal, may be largely offset by oil grooving in the lower bearing surface.

Oil grooves should be at right angles to the direction of motion of the revolving or sliding part. The grooves should always be cut to a point a short distance from the outer edges of the bearing—never to the edge.

Oil grooves are expected to perform the following functions:—

1. To hold the lubricant in the bearing.

2. To distribute the lubricant in a lateral direction (that is, sideways) over the surface of the bearing.

3. To return the lubricant that works over to the edge of the bearing, towards the centre.

There should be no sharp edges where the bearing is cut to make an oil groove, as these edges increase the wiping effect and may act as scraping edges. If the edges of the grooves are rounded, as shown at *N* in Fig. 43, the wedges formed aid in the flowing or wedging of the lubricant, between the bearing surface and the journal. An incorrect or sharp-edged oil groove is shown at *B*.

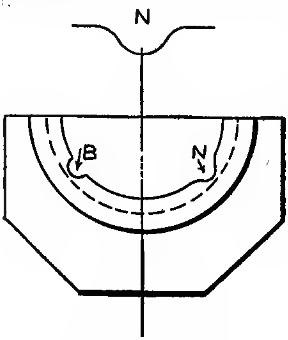


FIG. 43.—Oil grooves.

THE LUBRICATION OF SLIDING CONTACT BEARINGS

The Coefficient of Mechanical Friction.—The coefficient of mechanical friction, with respect to bearing lubrication, is affected by, and is dependent upon, many conditions. The steadiness of the bearing pressure and the nature of the motion have much influence on the mechanical friction of a bearing. The form of the surfaces of contact—whether flat or cylindrical—and the character of their contact—whether a surface, point, or a line—are all factors affecting the coefficient of mechanical friction.

For any two metals of the same character of surface, the same lubricant and pressure, the coefficient of friction is far from being constant. For example, in a high-speed engine of the reciprocating type the allowable bearing pressures permitted by good engineering practice, for each square inch of bearing surface (projected area), may be roughly given as follows:

1. Cross-head guides	150 pounds
2. Shaft bearings	400 pounds
3. Cross-head pin	1200 pounds
4. Crank pin	600 pounds

It is evident that, although the metals in contact are usually the same and the character of the surfaces are identical, nevertheless the allowable unit pressures for these bearings differ in each case. These wide differences are due to the fact that it is necessary to work with a different factor of safety for the coefficient of friction, for each case.

Working Heat.—A bearing is so proportioned, that at its maximum pressure and rubbing speed, its temperature, with good lubrication, shall not rise above a "working heat," so that seizing shall not occur, due to expansion.

Methods of Feeding Lubricating Oil to Bearings.—Bearings may be lubricated with oil, by any one of, or by a combination of, the following named methods:—

1. Hand feed (cup feed).
2. Ring feed (self-oiling bearing).
3. Gravity feed (flooded lubrication).
4. Forced feed (circulating system).
5. Splash feed.

Usual Methods of Feeding Grease to Bearings.—Grease is usually fed to bearings by one of the following methods:—

1. Hand-feed grease cups.
2. Compression grease cups.
3. By exposing the journal to a block of the grease and allowing the frictional heat of the bearing to melt the grease and cause it to flow.

OIL LUBRICATION

Hand Oiling.—Hand oiling is effected by hand oil cans direct to the bearing, or by hand-filling independent oil cups, arranged to feed oil to each desired point of lubrication.

Oil cups are equipped with "sights" to note the rate of oil feed. These cups are equipped with small valves by which the rate of oil fed may be adjusted. They are usually tapped into the bearing cap of the bearing, the oil being fed onto the top of the journal and distributed over the bearing surfaces by the rotative action of the journal, with the assistance of the oil grooves.

With hand oiling there is a large waste of oil, because of the difficulty in regulating the flow of oil to just the proper amount required by each bearing. After passing through a hand-oiled bearing, the oil can be partially recovered only by means of drip pans, and there is consequently a considerable loss, even under the best operating conditions. Grit and dirt often cause considerable trouble when hand oiling is used, and the close attention necessary to maintain any sort of efficiency from a lubricating standpoint, makes hand oiling dependent entirely upon the personal efficiency of the operator.

Ring Feed.—Ring- or chain-fed lubrication consists in hanging a ring or chain on the journal, so that, when it rotates, the rings will turn with

it. These rings dip into a reservoir underneath the bearing and carry the oil which adheres to them up to the upper surface of the journal.

A typical "ring bearing" is shown in Fig. 44.

Oiling Rings.—The rings used for ring feed must be smooth and free from any sharp edges that would cause interference with their free movements. The bearing must be so adjusted that the rings do not vibrate or jump.

The reservoir should be large enough to permit the oil returning from the bearing to have sufficient time to cool, before it is again drawn up to the journal surface.

There have been cases where hot running, ring-oiled bearings have

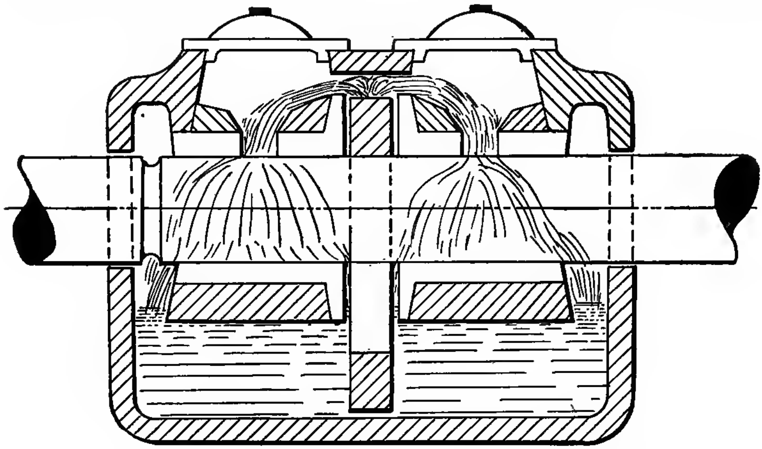


Fig. 44.—Bearing equipped with ring-fed lubrication.

been made to run cool, by increasing the amount of oil held in the reservoir, so that there would be a better cooling effect.

Gravity Feed.—A gravity feed system consists of an oil reservoir or tank, which is placed at a higher point than any of the bearings to be fed. From this tank a main supply pipe is run to the base of the engine and the various feed pipes are tapped into it, to carry oil to the different points of lubrication. The rate of feed at each bearing is regulated by a sight feed and needle valve, so that the various points of lubrication may receive individual adjustment.

Gravity feed systems are usually of the continuous, circulating feed type. In this type the oil running from the bearings is allowed to drain into a drip pan and is then drained to a settling tank. The dirty oil is

then passed through a filter and again raised up to the gravity tank by means of a small pump, which is usually driven by some oscillating part of the machinery. From the gravity tank it is again put into circulation. A typical continuous circulating, gravity oiling system is shown in outline in Fig. 45.

The chief advantage of the above-described oiling system is the copious supply of oil which it permits supplying to all of the points of lubrication.

Wear of Oil.—It has been demonstrated by numerous tests that a good grade of oil (petroleum) may be circulated for many months in circulating system without any appreciable deterioration of its lubricating

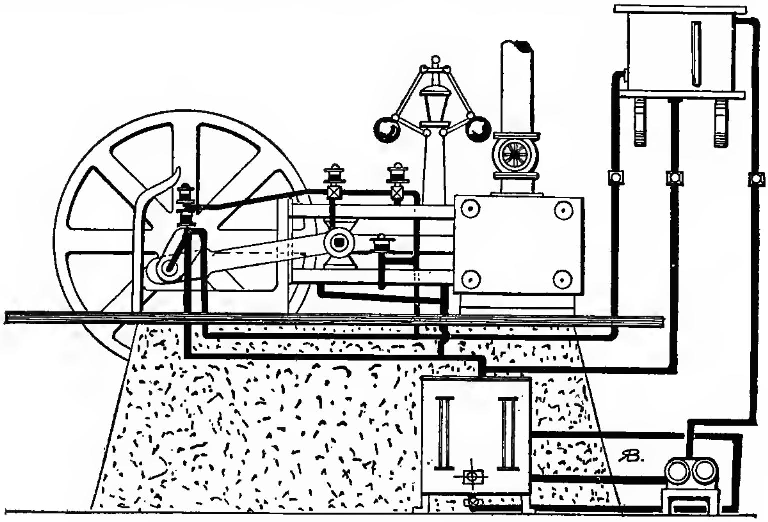


FIG. 45.—A typical continuous gravity oiling system.

qualities. Occasionally, as the more volatile portions of the oil are driven off by the heat in the bearings, a small amount of fresh oil should be added to prevent the body of the oil from becoming too viscous or thick.

Overflow.—There should always be an overflow pipe from the reservoir or gravity tank, so that in case the feeds become clogged or reduced, the excess of oil will be returned to the filter. A circulating system does away, to a more or less extent, with the personal factor as an element of lubrication.

Oil for Circulating Systems.—The oil for the continuous feed oiling system should be strictly a neutral, filtered oil. Paraffine or treated oils should be avoided, because of the possibility of emulsification from the

frequent churnings and the possibility of moisture getting into the system from condensed steam or from other sources.

Notes on Gravity Oiling Systems.—Combination oil cups and sight-feed needle valves should be used at all points of lubrication. The oil cups should always be kept full and ready for instant use in case the circulating system fails.

The gravity reservoir should have a large capacity, so as to provide a safe margin of safety for the supply.

Gravity systems are built either to supply one engine or a number of engines and machines from the same system. The size of the system is rated by the number of points of application of the lubricant or by the number of gallons of oil fed per hour or working day.

In large installations it is well to take a sample of the system oil every day or at frequent intervals for test, so that the need for fresh oil will be quickly detected by an unduly increased viscosity.

For all gravity feed systems the point of entry of the oil to any bearing should be at the point of minimum pressure in the oil film.

Filters for Circulating Systems.—A properly designed system should be equipped with sufficient filtering capacity to permit the continuous feeding of a copious stream of clean oil to all bearings. The following table gives the average capacity required for a system to supply slow, medium-speed, and high-speed engines:—

TABLE 23

FILTERING CAPACITIES FOR GRAVITY SYSTEMS TO SUPPLY SLOW-SPEED AND MEDIUM-SPEED ENGINES

Engine horse-power	Capacity of filtering unit gallons per hour	Engine horse-power	Capacity of filtering unit gallons per hour
100	4.25	1000	21.50
150	5.00	1150	25.00
200	6.00	1300	30.00
250	7.00	1500	40.00
350	10.00	2000	75.00
500	12.00	2500	110.00
750	18.00	3000	145.00
	HIGH-SPEED ENGINES		
100	5.5	350	13.00
150	6.5	500	15.50
200	8.0	750	24.00
250	9.25		

NOTE.—Engines running at 150–300 R. P. M. are classed as ***high speed.***
Engines running at 125–150 R. P. M. are classed as ***medium speed.***
Engines running at 75–125 R. P. M. are classed as ***slow speed.***
Engines running at up to 75 R. P. M. are classed as ***very slow speed.***

Location of Reservoir.—Considerable latitude may be assumed in the location of the reservoir, filter, and circulating pump. It is very important, however, that the gravity reservoir be placed at the highest point in the engine-room, so as to produce a good head of pressure for a positive and uniform flow of oil to all of the bearings.

In small systems the filter is often used as the reservoir, and is located in an elevated position. The filter should be easily accessible for frequent cleanings, as the success of these systems depends upon a clean filter of sufficient capacity.

Main Valve.—The main supply pipe from the reservoir should be equipped with a valve, to permit the shutting off of the flow to the whole system.

FORCED-FEED LUBRICATION

When bearing pressures and speeds are high it is necessary to force oil under pressure into the bearings, and this type of lubrication is called " forced feed."

Rate of Flow.—The rapidity of flow of the oil through the bearings must not be excessively high. There is a rate of flow for each operation that will produce the best efficiency. The oil must have sufficient time to absorb the frictional heat and thus carry it away from the bearing.

Pressures.—For horizontal bearings, forced-feed oil pressures range from 15 to 30 pounds to the square inch. For thrust and step bearings the pressures are much higher, depending upon the load carried.

Point of Entry.—In designing a forced-feed system, care must be taken not to introduce the oil into the bearings at such points that it will pass through the low-pressure areas of the oil films, causing counter-currents in the films and escaping without carrying off its proper share of frictional heat.

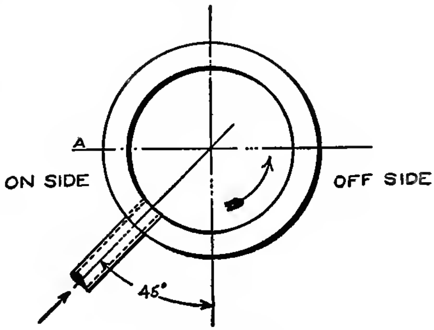


FIG. 46.—Point of entry.

This often results in an overheated bearing, although there is apparently a sufficient amount of cool oil being circulated through the bearing. Some authorities recommend that the point of entry be located at a point 45 degrees off the vertical axis of the bearing, on the " on side " of the film, as indicated in Fig. 46. The best practical results seem to be

obtained by locating the point of entry in the "on side," at the horizontal axis, as indicated at "*A*" in the figure.

Lubricating Oil for Forced Feed.—The oil used in all forced-feed oiling systems must be a neutral, filtered, absolutely non-emulsifying oil. For the usual turbo-alternator installation, an oil of 150 to 180 Saybolt viscosity at 100° F. (P. B.) will give the best results. The oil should have a low-gumming test and be free from any impurities. Treated oils are not satisfactory. It is needless to state that the oil must be free from any compound, and must be a strictly straight mineral oil.

Cooling.—In most systems the hot oil coming from the bearings is passed through a cooling tank, and cooled by coils of pipe containing running water.

Water-jacketed Bearings.—One of the results accomplished by forced-feed lubrication is the rapid reduction of frictional heat in the bearing, by the rapid flow of the oil through the bearing. For general practice, bearings using forced-feed lubrication do not require any additional cooling effect, but for very high pressures and speeds, water jackets must be used.

The specific heat of water, at its maximum density, is taken as 1.000, while the specific heat of the average petroleum lubricating oil at 60° Fahr. is approximately 0.4175. Since the specific heat of a liquid is a measure of its thermal or heat-absorbing capacity, it can readily be seen that a water jacket will carry off a large percentage of bearing heat. The cooling water is carried through small pipes, or channels, located as closely as possible to the lining of the bearing. Great care must be exercised not to permit any water entering the system and mixing with the oil, as the result will be a large increase in the friction produced in the bearings, due to the reduced efficiency of the oil, and this increase in frictional heat will defeat the very purpose of the water jacket.

For tests, showing the actual increase in friction, due to various percentages of oil and water, refer to the curve plotted from running tests, as shown in the section under the heading of "Marine Lubrication."

FLOODED LUBRICATION

Flooded lubrication consists in supplying a continuous stream of oil to the bearings, but differs from forced-feed lubrication in that the oil is circulated at a low pressure. The flow is usually much less in quantity, as compared to forced feed.

The circulation of the oil may be maintained by a pump or by a gravity tank (gravity feed). Flooded lubrication is often used for large roller bearings, as found in the step bearings of vertical turbo-alternators, and a system similar to the ordinary gravity feed is used, the difference being that the oil is piped directly to the bearing in a continuous stream, instead of through sight feeds. There is usually a cooling coil in the system to reduce the oil temperatures.

Roughly speaking, about one-quarter as much oil is circulated, for the same amount of bearing area, in a system supplying flooded lubrication as in one supplying forced-feed lubrication.

Wear of Oil.—Experiments that have been made by Professors Carpenter and Sawdon at the Cornell University, to determine whether lubricating oil " wears out " when used continuously in circulating systems, have indicated that, while the oil gained in gravity and viscosity, due to its volatile constituents having been driven off by the heat in the bearings, nevertheless the friction tests gave a slightly lower coefficient of friction at low pressures, and a slightly higher coefficient for high bearing pressures with samples taken from a well-designed, central oiling and filtering system, supplying flooded lubrication, as compared to tests made on samples of the same oil that had not been used in the system. Fnough fresh oil must be frequently added to the system to maintain a fairly constant viscosity.

SPLASH-FEED LUBRICATION

While splash feed is used only on individual units, it may supply lubrication to several bearings in that unit. The lubrication of the crank pins of certain types of engines is accomplished by splash feed. The engine frame is made to form a reservoir, and the crank at each revolution dips into the oil, throwing it onto the rubbing surfaces. Either horizontal or vertical stationary engines may be equipped with this form of lubrication. Many types of internal-combustion engines use the splash system for main bearings, crank, cross-head, and wrist-pin lubrication. The cylinders of many vertical internal-combustion engines are also lubricated splash feed.

Splash feed is apparently very economical and not wasteful of oil, but it has many disadvantages. The oil in the reservoir soon becomes saturated with particles of dirt and metal from the wear of the bearings,

and it is useless to expect satisfactory or efficient work from dirty oil. Steam, leaking past the piston-rod packing box and condensing in the crank-case, mixes with the oil, and unless the oil is a strictly neutral, non-emulsifying oil, untreated and free from any compounding, the result will be a thick, emulsified mass. Very often the emulsification of oil used in crank-case, splash-feed lubrication is caused by the use of excessive amounts of boiler compound in the boiler. This compound may be carried over with the steam, by excessive priming in the boiler, and then after leaking past the piston-rod packing box into the crank-case, may combine with the oil and cause it to form a soapy, emulsified mass. This condition is of course immediately blamed on the oil, but if it is a pure, strictly neutral oil, the location of the steam separator, its condition, and the boiler compound should be investigated as being the real cause of the complaint.

The fact, that the engine frame is generally warm, prevents the oil from being sufficiently cooled in the crank-case, and this is a very serious objection to splash-feed lubrication.

"HOT BOXES"

Hot Bearings.—A "hot box" or overheated bearing may be due to any one of several causes, as follows:—

(*a*) The bearing may be receiving an insufficient amount of oil.

(*b*) The journal shaft may be "out of line."

(*c*) The lubricant may be unsuitable.

(*d*) In the main bearings of engines, overheating may be caused by too little compression in the steam cylinder, which should act as a cushion for the inertia of the reciprocating parts at the end of the stroke. When this compression is lacking, the oil film is subjected to alternate high and low pressures, which tends to impair its uniformity.

Remedy for Hot Boxes.—The first step in the adjustment of a hot box is to loosen up the bearing all around; then give it a generous supply of cylinder oil through the oil hole, or feed the bearing a mixture of one part graphite and ten parts of heavy engine oil.

Warm Bearings.—There is no reason to expect that a bearing should run cold, and in a normal bearing the temperature will rise to a point where the rate of heat being produced in the bearing is just balanced by the rate

of radiation of this heat by the metallic parts to the surrounding air, plus the heat carried away by the oil and the engine frame. Those in charge of engines should familiarize themselves with the various normal running temperatures of the bearings of the machines under their care. Large machines and high-speed equipment should be provided with thermometers on the bearings, to indicate the running temperatures.

Clearance Factor.—If a bearing is to be provided with clearance to prevent binding, a "clearance factor" should be used.

The diameter of the journal, multiplied by the coefficient of expansion of the metal composing it, and the probable range of temperature under running conditions, will give the clearance diameter for the bearing.

Water.—Sometimes a stream of water is run on an overheated bearing or crank-pin to cool it off. This should never be done, except as a last resort, and only in cases where the engine must be kept running at all costs, until such a time when it may be shut down for repairs. Serious distortion will probably result from this practice.

Babbitted Bearings.—These bearings should be examined after a hot box, because the oil feeds may be clogged, or at least partly clogged, by melted metal. If trouble from overheating occurs in a babbitted bearing, it should be opened, and any spots that appear to be darker than the rest of the bearing should be scraped, as these are the high spots.

Brass and Bronze Bearings.—If a hot box occurs in a brass or bronze bearing, it will probably be distorted by the heat and should be refitted. Coat the journal surface with red lead and apply the brasses, and then slide them around the journal. The high spots on the brasses will be indicated by red lead sticking to them. These spots should be scraped and filed, until the whole surface of contact is covered with red lead, when the brasses are applied to the journal, as above described.

SPECIAL CASES

Frequently, semi-enclosed bearings are encountered, which are difficult to lubricate. Such a bearing as shown in Fig. 47 may be successfully lubricated with oil by using felt, as indicated in the drawing. The oil may be held on the bearing by this method, and, while it does not produce the best results, it nevertheless accomplishes the purpose. Fresh oil is supplied through the oil cap and onto the felt.

COLLAR BEARINGS

There is little aid given by the contact surfaces of a collar bearing towards lubrication. Usually forced or flooded lubrication is necessary for the lubrication of this type of bearing.

BALL AND ROLLER BEARINGS

Difference Between the Requirements of Lubrication of Sliding and Rolling Contact Bearings.—The amount of friction developed by a journal or shaft with surface contact and sliding motion is larger or smaller, depending upon the efficiency of the bearing lubrication. This is true, because in sliding contact bearings there must be no metallic contact between the sliding surfaces, if excessive friction is to be avoided.

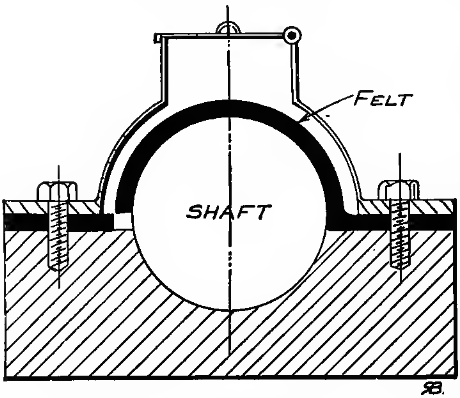


FIG. 47.—Method of applying oil lubrication to a semi-enclosed bearing.

In the case of roller or ball bearings, however, there is always metallic contact between the balls and the bearing surfaces. This contact is of a rolling nature, and for a ball bearing the contacts are points and for a roller bearing the contacts are lines.

Speeds.—The speeds of roller and ball bearings can be carried very high, greatly exceeding any possible speeds for bearings with sliding contact. In the case of step or thrust bearings, carrying high loads, the maximum bearing pressures per unit load area, for sliding contact bearings, is much lower than the maximum loads permissible with ball or roller bearings.

BALL BEARINGS

Ball bearings are those in which the load is carried by a number of steel balls, very accurately finished and polished, which are held in place by grooved rings, called " races."

A radial ball bearing is shown in Fig. 48, and is designed to carry radial loads. Referring to the figure, *A* is the outer race, *B* is the inner race, *C* are the hardened steel balls, and *D* is the opening to permit the insertion of the balls.

The load-carrying capacity of the bearing is directly proportional to the number of balls. To secure the full carrying capacity, the balls must represent as close an approach to true spheres as it is possible to realize. All of the balls must be exactly alike in size, because if one ball is larger than the rest it will receive more than its share of the bearing load, while an undersized ball will be underloaded. To secure an even division of the load, the balls should not vary more than one ten-thousandth of an inch in diameter.

Ball Cage.—A " cage " is a small spacing block used to keep the balls separated, to reduce the noise of the bearing, and to obviate, to a more or less extent, certain forms of wear.

The noise made by radial ball bearings when running is caused by the

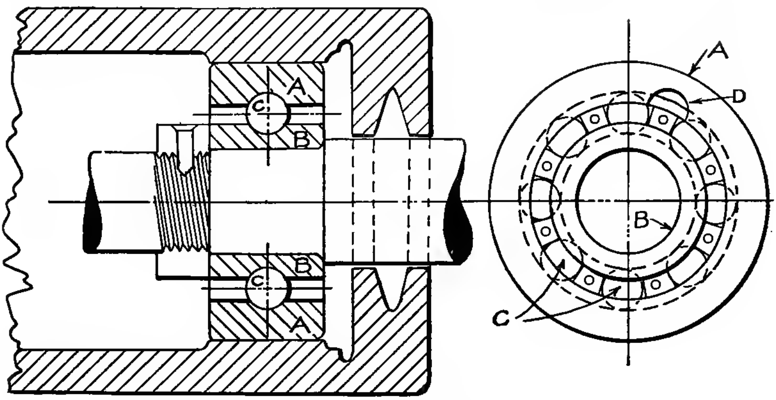


FIG. 48.—Radial ball bearing.

removal of the load from the different balls as they roll through the area of maximum pressure and up to the point of no load. When a ball passes from the area of pressure it snaps forward against the ball in front of it and then against the outer race, causing a clicking sound. Ball bearings are also made with two rows of balls.

THE LUBRICATION OF BALL BEARINGS

The question of lubrication is very important in the successful operation of ball bearings. Oil is essential for the operation of sliding bearings, but it is not generally known that ball bearings also require a certain amount of lubrication. It is a very common occurrence to find machinery equipped with ball bearings, where these bearings are allowed to run

entirely dry. There is a slight rolling action between the balls and the separator, and a lubricant must be interposed to reduce the consequent friction.

The lubricant used in ball bearings must be neither acid nor alkali, but must be neutral. A simple test for ball-bearing lubricants may be made by coating a highly polished steel surface with the oil or grease under observation. After exposing it to the heat of the sun for several days, any corrosive tendencies will be evident upon the polished surface of the plate. Oil containing any compounding of animal or vegetable oils should never be used in ball bearings, as it will produce gumming and become rancid. The best lubricant for these bearings is a strictly mineral oil. For high-speed bearings, a light machine oil should be used, and for slower moving bearings use a heavy viscous oil or a straight petroleum grease. Petroleum greases have poor viscosities, however, and quickly run out of the bearings. Well-designed bearings are provided with suitable retainers for the purpose of holding the lubricant in the bearing and preventing its creeping out along the shaft. Engine grease or cup grease should not be used in ball bearings unless it is carefully tested for the presence of free alkali, which will pit and corrode the bearing if present. Greases should not be used in ball bearings running at over 1200 R. P. M. Graphite is not satisfactory for use in ball bearings, because of its tendency to pack. Oil is the best all-around lubricant for these bearings.

Ball bearings should be frequently flushed out with gasoline to keep them clean.

NOTES ON BALL BEARINGS

Many ball bearings are equipped with felt packing to keep the lubricant in the bearing and to keep the dirt out. Felt washers frequently cause trouble, by losing their contact with the shaft, due to felt hardening, and they then wear away quickly.

A good plan is to encircle the felt washer with a wire spring ring so that this pressure will keep the felt in contact with the shaft. The felt should be saturated with a filtered, straight mineral cylinder oil, of about 145° Vis. at 212° Fahr.

Effects of Rust.—Rust is destructive to a ball bearing. It can be recognized, even in a bearing that has been cleaned free from red rust, by the presence of pronounced pits, not only on the race surfaces, but on

the other parts of the bearings. "Rust pits" are generally all over the bearings, while "overload pits" are confined to the ball tracks and to the balls themselves.

"Pitting," due to the presence of free acid or alkali in the lubricant used, may be easily distinguished from that due to rust or overload, since the pits show up as clearly defined etchings. Overloaded ball bearings do not wear, but the polished surfaces of the races and balls will be destroyed. This is indicated by small "pin holes" and "chipping."

Dust and dirt quickly damage the highly polished surfaces of the balls and races. The drain holes and oil holes of the housing must be kept closed by a cap to avoid leakage of the lubricant and the entrance of dirt.

ROLLER BEARINGS

Types.—There are two general types of roller bearings; namely, those with hardened steel solid rollers, and those with flexible, helical, hollow rollers.

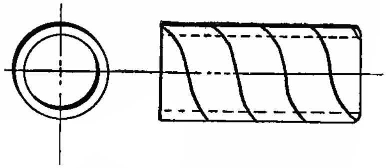


FIG. 49.—Flexible roller bearing.

Roller Bearings.—"Roller bearings" consist of a steel sleeve, which fits on the shaft and on which the rollers travel. The "yoke," or "cage," holds the rollers in place, and an outer shell surrounds the rollers and carries the load.

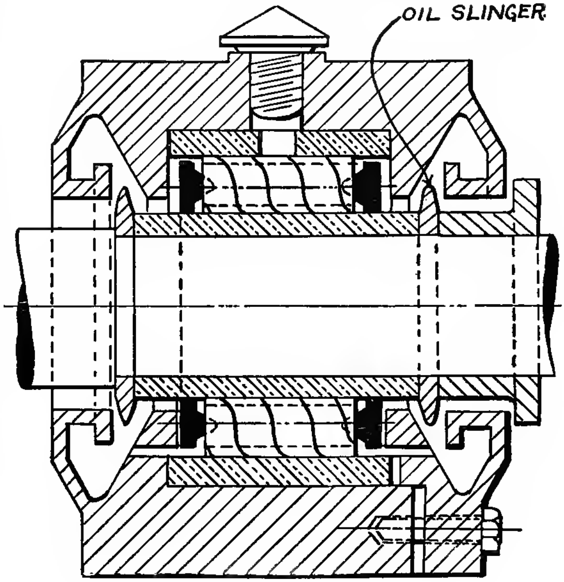


FIG. 50.—Roller bearing with flexible rollers.

Journal roller bearings having solid rollers may be equipped with either cylindrical or conical rollers. Solid roller bearings found in automobiles usually have conical rollers, while those found in machinery usually are equipped with cylindrical rollers.

Journal bearings which

are equipped with flexible, hollow rollers have cylindrical rollers only. These rollers are made by winding a flat strip of steel into a hollow coil, as shown in Fig. 49. Their chief advantages over the solid type of rollers are (*a*) their flexibility, which permits of a slight irregularity in the bearing alignment; (*b*) their capacity for carrying a supply of lubricant within their hollow interiors; and (*c*) the assistance given by the helical grooves in the distribution of the lubricant, by screwing it along over the roller surface.

A typical flexible roller bearing is shown in Fig. 50.

THE LUBRICATION OF ROLLER BEARINGS

A heavy-bodied oil or a medium grease should be used for the lubrication of roller bearings when the speeds are low; but under normal conditions the speeds are high enough to permit the use of a medium-bodied machine oil.

The helical cracks, on the surfaces of the rollers of the flexible type, give the best service with a medium-bodied oil, if the bearing is so designed that suitable provision has been made for the retention of the oil in the bearing.

The pressures on these bearings are usually about 450 pounds per square inch of developed bearing for a speed of about 50 R. P. M., which would be considered an extreme low speed and a maximum load.

For heavy duty bearings running at 1000 R. P. M. the unit load may run as high as 800 pounds per square inch. The speed of these bearings rarely exceeds 3000 R. P. M.

A pure, semi-fluid grease makes an excellent lubricant for this type of bearing. The grease should be particularly free from gumming defects and should retain its body well, when heated in the bearing.

Solid Roller Bearings.—Solid rollers are sometimes used in heavy bearings of the high-speed thrust type, such as are found in large vertical turbines. The rollers used in this type of bearing are short and have large diameters, due to the fact that in their circular path their motion is a combination of a sliding-rolling motion.

The demands made upon the lubricant for this type of bearing are excessive. The contact lines of the cylindrical surfaces of the rollers give practically no bearing surfaces, and the wiping effect produced by their travel in a circular path, which tends to scrape the lubricant from

the bearing plates, requires that the supply of oil be excessive, so that the wiped-off oil is immediately replaced by fresh oil. These bearings are therefore usually run in flooded lubrication, the oil being pumped through a hole in the lower bearing plate (B) (see Fig. 51) into the space below the inside edge of the rollers and separated from the shaft by an oil guard, as shown at N in the figure. The oil rises, due to the suction produced by the centrifugal action of rollers and to the force of the feed, which may be produced by a pump or by gravity. It is drawn into the

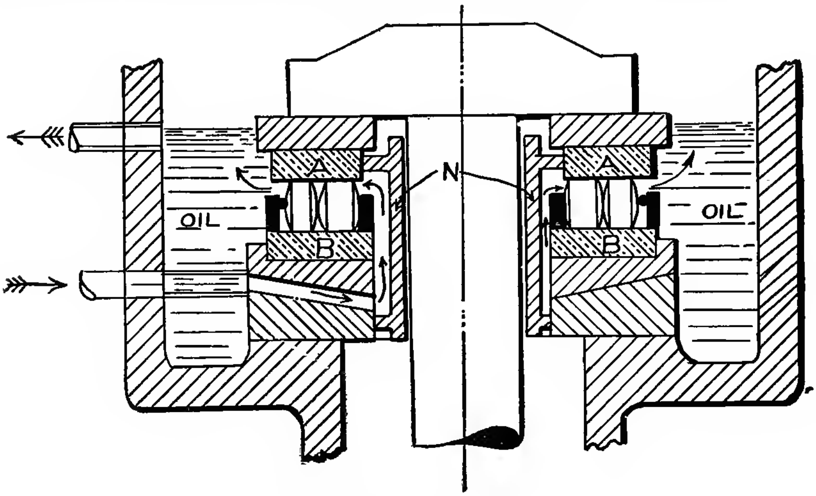


FIG. 51.—Vertical roller bearing.

spaces between the rollers and is thrown out, from the outside ring of rollers, by their centrifugal action, combined with their wiping action. The oil is allowed to overflow above the upper bearing plate (A), to a filter and settling tank, from which it is again drawn for circulation.

The total loads on these bearings are often as high as 175 tons, and the speeds may be as high as 95 R. P. M. The oil used should have a viscosity of about 145 to 160 Saybolt (P. B.) and 175 to 180 Saybolt (A. B.).

The oil must be a strictly filtered neutral oil and free from any emulsifying tendencies.

CHAPTER XI

THE LUBRICATION OF STEAM CYLINDERS

THE proper and satisfactory lubrication of the valves and cylinders of steam engines offers one of the most difficult problems met with in practical lubrication.

Steam cylinder lubricants must perform their work under the most unsatisfactory conditions and in an inaccessible place, where the detection of poor lubrication is difficult.

The cylinder lubricant must first be atomized by the incoming steam and then carried to the cylinder walls and valve seats. These surfaces are in a most unfavorable condition to receive the lubricant, as they are hot and wet.

The wiping effect of the piston and valve tends to destroy the film of lubricant, since their motion is in a straight line, and the washing effect of the water of condensation also aids in the destruction of the film.

The following conditions have an important bearing on steam cylinder lubrication:—

1. The kind of engine.
2. The steam pressure.
3. The condition of the steam (wet or dry).
    (*a*) Superheat (how much?).
4. The rubbing speed of piston.
5. The method of feed of the cylinder lubricant.
6. The diameter of the cylinder.
7. The location of the separator and distance of the engine from the boiler and the condition of the pipe covering of the steam line.

(1) **Kind of Engine.**—The information required under this heading is intended to indicate the kind of valve and valve gear of the engine; *i.e.*, Corliss, Plain Slide Valve, Piston Valve, etc.

These valves are described in the section of this book referring to steam engines, and their mechanical construction requires individual consideration of their lubricating requirements.

(2) **Steam.**—Steam having a temperature due only to its pressure is called "Saturated Steam."

Steam which has been heated to higher temperature than that due to its pressure alone, is called " Superheated Steam."

Steam Pressure.—The pressure, of the steam supplied to a steam cylinder, is an important guide in the selection of a lubricant for that cylinder. By reference to standard steam tables, the temperature of the steam may be directly determined if the steam is " saturated," and may be obtained by adding the number of " degrees superheat," if the steam is superheated. Table 24 gives the approximate temperatures, to the nearest full degree Fahr., for saturated steam at various gauge pressures.

TABLE 24

GAUGE PRESSURES AND NEAREST FULL DEGREE TEMPERATURES FOR SATURATED STEAM

Gauge pressure, pounds per square inch	Temperature Fahr.	Gauge pressure, pounds per square inch	Temperature Fahr.
1	216	125	352
5	227	130	355
25	267	140	360
50	297	150	365
60	307	160	370
70	316	170	375
80	323	175	377
85	327	180	379
90	331	190	383
95	334	200	387
100	337	215	393
105	341	235	400
110	3[illegible]	245	404
115	347	265	411
120	350		

NOTE.—The nearest full degree is taken as being accurate enough for use in practical lubrication and the table is therefore only approximate.

(3) **Normal Steam Temperatures.**—It will be noticed, by reference to the steam table, that the temperature of saturated steam, at pressures even as high as 265 pounds, is only 411° Fahr.

Any petroleum cylinder oil will have a flash test exceeding this temperature, so that for normal steam conditions,—that is to say, with no superheat,—no particular attention need be paid to the flash test of the oil.

Superheated Steam.—Superheated steam is described as having a number of " degrees superheat." This refers to the number of degrees Fahrenheit, by which the temperature of the steam exceeds the normal temperature of saturated steam at the same pressure.

The temperatures of superheated steam range as high as 600° Fahr., and sometimes exceed even that temperature.

Superheated steam does not contain any moisture. Steam is superheated to increase the economy of the engine by reducing the number of pounds of steam or water required by the engine per horse-power per hour.

Due to the lack of moisture and high temperatures, steam cylinders using superheated steam are subjected to different conditions from those met with in cylinders using saturated steam.

The chief requirements for a cylinder oil to be used for the lubrication of cylinders using superheated steam are high flash-point and good body.

Since there is practically no moisture from condensation water in cylinders using superheated steam, it is recommended that the cylinder oil used, be a straight mineral, uncompounded oil. It should be unfiltered and have the highest possible viscosity and flash-point.

The usual cylinder oil for this purpose has a viscosity of 315° to 325° Say. at 212° Fahr. and a flash-point of 625° to 640° Fahr.

Steam Cylinder Lubrication Notes.—A steam cylinder is alternately a condenser and a boiler. The cylinder walls are heated, by the heat given up by the steam due to condensation, and the condensed water is boiled again and largely vaporized during the exhaust. Cylinder oil is therefore compelled to resist the "washing effect" of the condensation water, by emulsifying with it, and then to resist the vaporizing effect to which it is subjected during the exhaust stroke.

In the usual steam cylinder, there will be from ¼- to ¾-inch depth of condensation water on the bottom of the cylinder. Often this depth will be exceeded to a depth of ½ inch, and it is not an unusual case to find the low-pressure piston of a compound engine practically running in water.

Cylinder Oil Compounds.—In order to aid the emulsification of cylinder oils with the condensed steam, they are compounded with acidless tallow oil, and in some of the inferior oils with "degras" (wool grease).

Acidless tallow oil should always be used for compounding, and never the cheap and deposit-forming degras.

The percentages of tallow oil used for compounding purposes will run from 3 per cent. for ordinary dry saturated steam conditions to 10 per cent. for low pressures and wet steam and long-uncovered steam lines, where the percentages of moisture in the steam will be high.

Cylinder Condensation.—The amount of condensation in a steam cylinder depends upon the range of temperatures of the steam; that is, difference between the temperatures of the admission and exhaust steam.

The time of "cut-off," whether early or late in the stroke, and the speed of the engine affect the amount of condensation. Engines using the same quality of steam and running at 400 R. P M. are found to have only about one-half the relative amount of condensation as is found in engines running at 100 R. P. M.

Temperature Range.—The temperatures of steam cylinder walls fluctuate. Some authorities have stated that this temperature range may approach one-half the steam temperature range. This theory is under dispute as to the amount of range, but the fact remains that there is a considerable fluctuation in these temperatures, which has a resulting effect upon the viscosity of the cylinder lubricant.

(4) **Rubbing Speeds.**—The rubbing speed of the piston has an important effect upon cylinder lubrication. The piston speed affects the amount of condensation and also is a gauge of the wiping effect existing within the cylinder.

When a low-speed engine is supplied with wet steam, the amount of condensation water to be met with will be high and the lubricant must be "adjusted" to meet it. In the case of high-speed engines, the amount of condensation water, under normal conditions with the same wet steam, is much lower.

(5) **Methods of Feed.**—Proper location of the feed pipe of the cylinder oil lubricator is very important in securing good atomization of the oil.

The best results cannot be secured, even with other favorable conditions, if the oil is fed into the steam between the throttle valve and the cylinder, or directly on top of the valves. This method of feeding does not favor the atomization of the oil, which is most necessary in order to secure the proper distribution of the lubricant over the surfaces to be lubricated. The cylinder oil, under these conditions, will mostly pass out with the exhaust.

Cylinder oil should be fed into the steam line at least three feet above the throttle valve, thereby insuring proper and complete atomization. The oil should be introduced into the steam line by means of a slotted pipe, as is shown in Fig. 52. The end of the feed pipe should extend to just past the middle of the steam pipe. This feed pipe should be slotted on the

bottom, as shown. If the feed pipe is screwed into the steam line flush with the inside surface, the oil will spread over the inside of the steam line and only a small amount of it will become atomized and be available to lubricate the cylinder and valve.

(6) **Diameter and Stroke of the Piston.**—This data is of value merely as a gauge as to the proper amount of oil that should be supplied to the cylinder, as from this data and the piston speed, the total square feet of surface rubbed over per day by the piston may be obtained and comparisons made with other similar engines, to check the relative amounts of oil used.

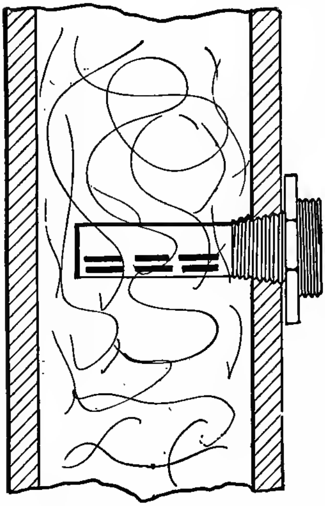


FIG. 52.—Method of admitting cylinder oil to steam line.

(7) **Location of the Separator.**—The location of the steam separator should be as near the throttle valve as possible, so that the steam will be dry. The separator should have a safe margin of capacity.

The distance from the boilers to the engine has an effect upon the amount of moisture in the steam. Long-uncovered steam lines are productive of wet steam. The pipes should have sufficient pitch downwards towards the engine so that the condensed water will flow in the same direction as the steam and thus tend to flow into the separator, or drip, instead of running against the flow of the steam and being picked up by it, with a resulting large amount of water in the steam.

STEAM CYLINDER LUBRICATORS

There are two general types cylinder lubricators; *i.e.*, the hydrostatic or displacement lubricator and the forced-feed lubricator.

Hydrostatic Cylinder Lubricators.—Fig. 53 shows a well-known hydrostatic lubricator.

The operation of this lubricator is as follows: Steam from the steam line is admitted to the exposed connecting pipe *D*, which should be at least five feet in length for the quart-size lubricator. In this pipe the steam is condensed and the hydrostatic pressure of the condensation water causes the oil, which is on top of the water in the body of the lubricator,

to pass down through the pipe *B*, up through the sight-feed glass *E* and into the steam line through the pipe *H*.

Care of Hydrostatic Lubricators.—All connections must be perfectly tight. Clogging of the sight-feed glass is sometimes due to the rubber ring at the bottom of the glass having been squeezed over the outlet into

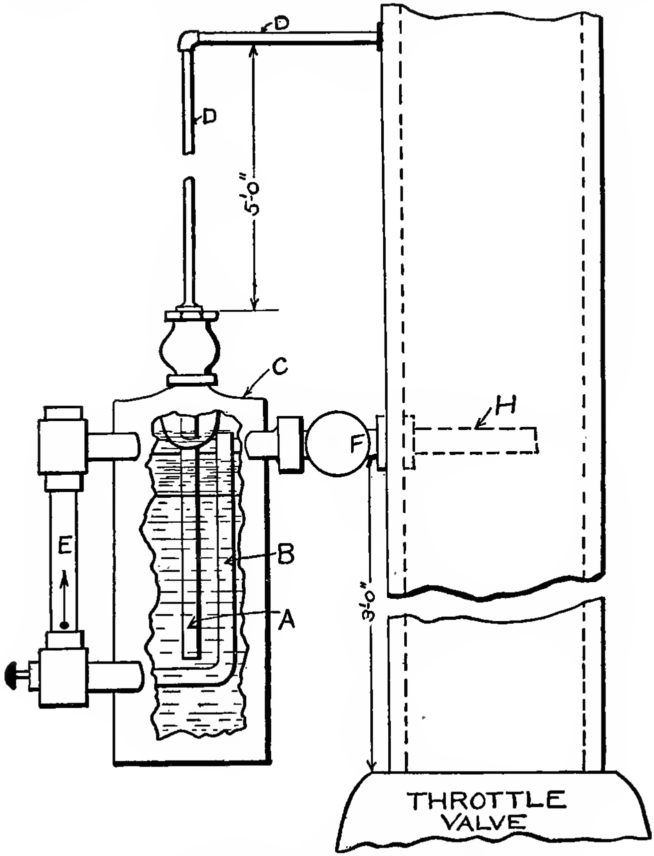


FIG. 53.—Typical hydrostatic cylinder lubricator.

the glass, or waste may have gotten into the outlet. The remedy is to remove the glass and clean the outlet.

Oil trailing up the side of the sight glass is usually due to a denting of the cone, which is located at the bottom of the glass. The remedy is to file down the cone, solder a fine wire to the side, and permit it to extend nearly to the top of the glass. The oil will then follow the wire and the glass will remain clean.

To reduce the size of the drops of oil being fed by the lubricator, fill the sight glass with glycerine, or a solution made of a teaspoonful of common table salt and the desired amount of water. The increased gravity of the fluid in the glass will cause the drop to break off from the cone before it has become as large as it would have become, with straight water in the glass.

To Clean the Feed Glass.—Remove the plug at the top of the upper connection and swab out the glass with a piece of waste, which has been soaked in kerosene and attached to a stick.

Notes on Hydrostatic Lubricators.—Never allow the lubricator to run empty, as the glass will get hot and cause oil to stick to it. In the engine-room, cylinder oil is usually kept limpid by placing it in a coffee-pot and allowing it to stand on top of the engine cylinder. A piece of asbestos should always be kept under the pot to prevent overheating and consequent injury to the oil.

"Churning" is caused by partially filling the lubricator with oil, and then if there does not happen to be enough condensed water in the lubricator to make up the rest of the capacity, steam will flow in and mix with the oil and churn it into a foam. When this occurs, empty the lubricator, allow it to cool, and refill it with oil and allow sufficient time for the formation of the proper amount of condensation water.

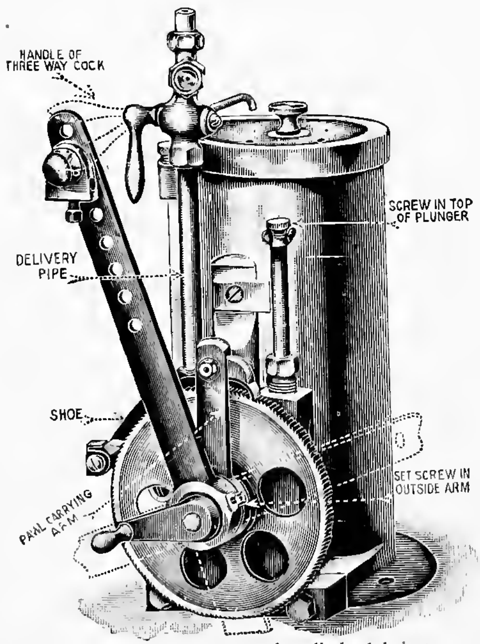


Fig. 54.—Rochester automatic cylinder lubricator.

Leaky joints cause irregular feeding.

FORCED-FEED CYLINDER LUBRICATORS

These lubricators consist of an oil chamber to which is attached one or more pumps, which are actuated by some reciprocating part of the engine. Forced-feed lubricators are positive in their action and are automatic

in their feed. As the engine speeds up, they will increase the feed to carry the increased demand upon the cylinder lubricant. They require very little attention.

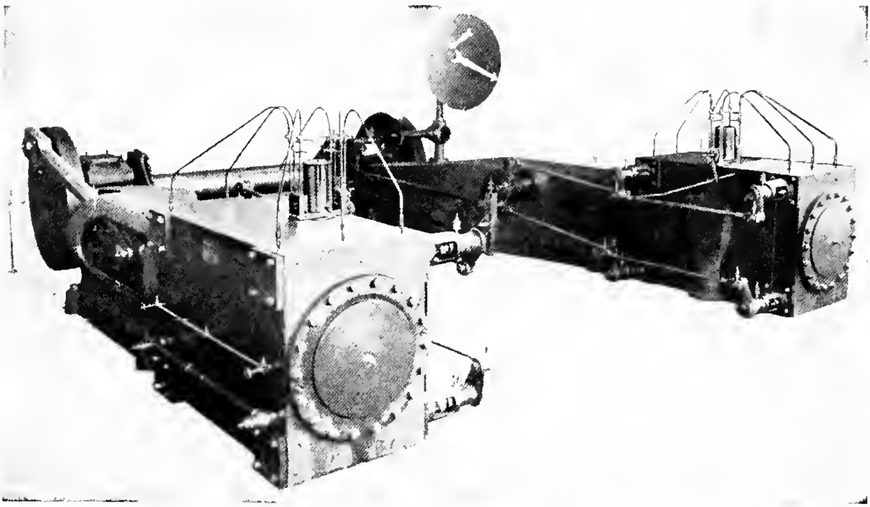


FIG. 55.—Sextuple feed Rochester automatic lubricators attached to a pair of four-valve hoisting engines.

Fig. 54 shows the well-known type of Rochester Automatic Lubricator. Fig. 55 shows two Sextuple Feed Rochester Lubricators, attached to a pair of four-valve hoisting engines built by the Vulcan Iron Works.

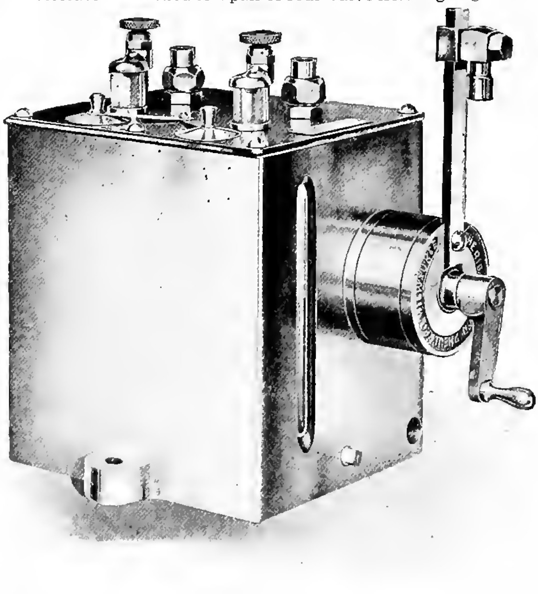


FIG. 56.—Two-feed Phenix forced-feed lubricator.

Fig. 56 shows a Two-feed, Phenix Forced-feed Lubricator, which is provided with a divided tank for holding two kinds of oil. Fig. 57 is a sectional view of the Phenix Forced-feed Lubricator, which shows a pumping unit. One of these pumping units is provided for each of the feed lines.

A short description of this type of lubricator is of interest and is therefore included, as follows: Referring to Fig. 57, a shaft that runs the entire length of the lubricator is driven by a lever and ratchet. Eccentrics are provided on the shaft which give a vertical up-and-down movement to each pumping unit. Each unit is a double pumping unit, composed of a lower pump which measures out a definite quantity of oil and forces it up through the sight-feed glass, from which the upper pump draws it and forces it out through the feed line. A sleeve carried upon the lower pump plunger may be adjusted to regulate the amount of oil fed for each stroke of the pumping plungers. When the sleeve is in its highest position, the entire amount of oil drawn in by the lower pump is forced out into the sight-feed glass, and when the sleeve is at a lower position, the pump plunger does not travel to the end of the cylinder and the amount of oil forced out is thus reduced. The location of the sleeve is regulated by the milled nut on top of the pump casing.

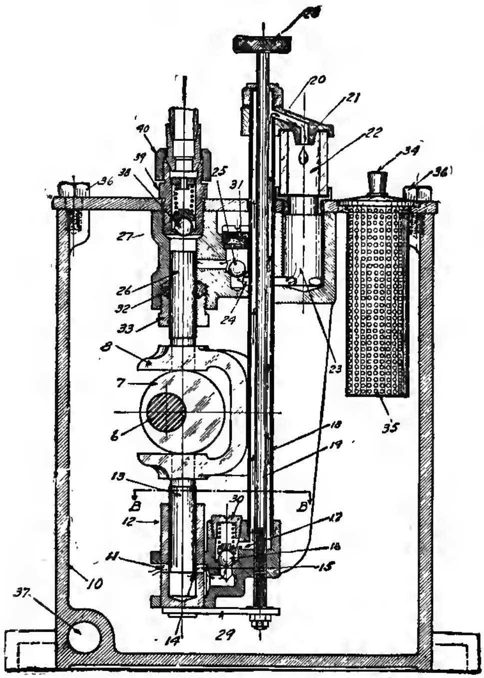


FIG. 57.—Sectional view of a Phenix forced-feed lubricator body and a pumping unit.

EXAMINATION OF STEAM CYLINDERS

A well-lubricated cylinder ought to appear dark and smooth, with no signs of bright polish, when the cylinder head is removed.

A slight rubbing with a piece of tissue paper should produce a bright polished surface, in contrast with the dark surface.

On opening the cylinder of an engine, a bright, mirror-like surface of the cylinder walls indicates poor lubrication. Many engineers believe that a bright, highly polished cylinder is an evidence of good lubrication, but it really is a proof of high frictional wear.

NOTES ON CYLINDER LUBRICATION

Cylinder Oil in the Boiler Feed.—Mineral oils, such as cylinder oils, that have passed out with the exhaust steam and been received by the hot well, may enter the boiler with the feed water.

Mineral oils form a brown, varnish-like coating, when deposited on the interior surfaces of boiler plates. This coating is a poor conductor of heat, and, due to this fact, the water in the boiler cannot carry the heat away from the plate fast enough and overheating of the plates may occur.

Drip Cocks.—Care must be taken to see that the drip cocks of the engine cylinder are tightly closed after starting. If these cocks leak, even a very little, practically no oil will be distributed under the valve to lubricate the seat, and the result will be a "chattering" of the eccentric and sticking of the valve.

Excessive Cylinder and Valve Friction may be detected by a groaning in the cylinder, vibration in the valve rods, and by heating of the eccentric.

STEAM CYLINDER DEPOSITS

When trouble is experienced with cylinder deposits, first examine the separator drain pipe. Very often the cause of the trouble will be found to be a clogged trap and pipe.

Often the piston rings have been set too tight and, as a result, they have scraped into the soft iron of the cylinder. These iron scrapings combine with the oil, due to the adhesive attraction between the oil and iron, and form a heavy deposit.

The usual analysis of deposits from steam cylinders will show the presence of iron. Engineers usually refer to such iron as being the result of metallic wear, due to using a poor lubricant. However, many of these deposits are found in those parts of the cylinder and valve chest where no metallic wear could have produced iron scrapings.

Most steam cylinder deposits consist of magnesium, sodium, etc., all of which have been brought over by the steam from the boiler. When combined with the oil in the cylinder, with a little iron rust added, these substances form the majority of the cylinder deposits that are usually unjustly blamed upon the cylinder oil.

A typical cylinder deposit would analyze as follows:—

Silica, magnesium, or earthy matter (mud)	40
Petroleum oil, with a small amount of saponifiable matter	35
Oxide of iron	20
Carbon	5
	100

Priming of Boilers.—The priming of boilers, with the resulting carrying over of particles of water mixed with solids, is one of the chief causes of cylinder deposits.

To illustrate the large amount of solids that may enter the cylinder by means of the steam, the following data is given: If a 100-H. P. boiler, evaporating 3000 pounds of water per hour, is operated with water containing 51.42 parts of solids to 100,000 parts of water, and the boiler is not cleaned out, at the end of a ten-hour day, 15.42 pounds of solids will have been liberated.

A large percentage of these solids will float upon the surface of the water in the boiler, and if there is any excessive forcing or slackening of the fires and priming should occur, it can be easily seen there is a strong possibility of a cylinder deposit being formed, unless the separator is very efficient.

EFFECT OF BOILER COMPOUNDS ON CYLINDER LUBRICATION

Boiler compounds usually consist of soda-ash, potash, caustic soda, or other substances of a similar nature, which have a very destructive effect upon cylinder lubrication, if they are carried over by the steam to the cylinder.

Very often a complaint from an engineer regarding his cylinder oil, or particularly, crank-case oil for vertical steam engines, may be traced to the excessive use of the above-mentioned compounds in the steam boiler.

These compounds may have been carried over to the cylinder, causing thickening of the oil, and may also have leaked out past the stuffing box to the crank case, with the resulting formation of an emulsion.

CHAPTER XII

OIL CUPS, GREASE CUPS AND FILTERS

Sight-feed Oil Cups.—Sight-feed oil cups are usually equipped with needle valves and may be obtained in capacities ranging from 5/8 ounce to one pint.

Fig. 58 illustrates the typical form of oil cup, of the quick-stop, glass

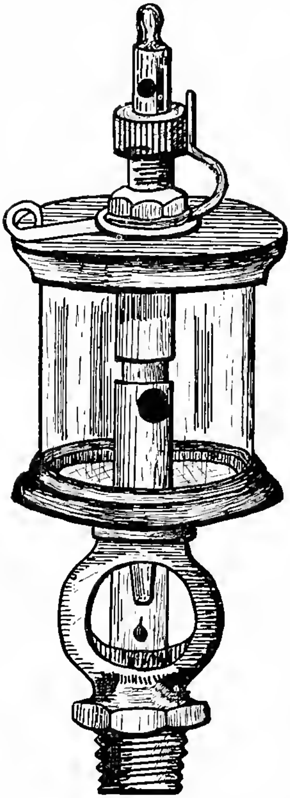


FIG. 58.—Sight-feed oil cup.

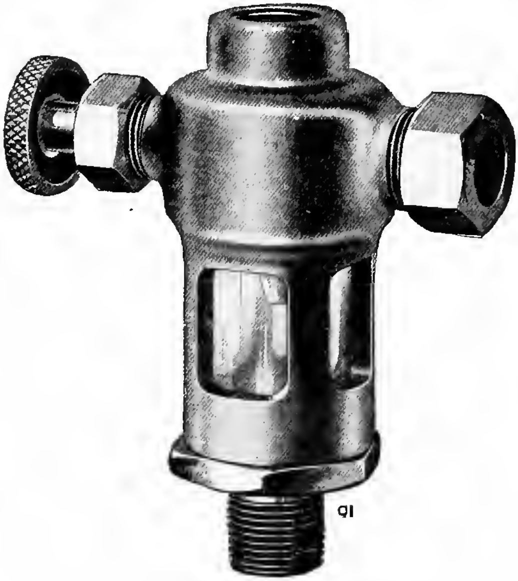


FIG. 59.—Phenix swivel sight-feed oiler.

body type. The valve stem is raised or lowered to regulate the feed of oil by means of a milled nut. When the lever is raised to the perpendicular position the cup is feeding, and when down in a horizontal position the feed is shut off. By turning the lever in a 45-degree position the bearing may be flooded with oil.

This type of oil cup is used for individual bearing and slide lubrication.

Sight-feed Oilers for Circulating Systems.—Fig. 59 shows the construction of the Phenix Swivel Sight-feed Oiler, made by the Richardson-Phenix Company, of Milwaukee, Wis.

These sight feeds are used at the various points of lubrication to regulate the flow of oil supplied by a continuous-flow system.

An adjustable needle valve, with a stuffing gland and milled nut, regulates the flow, which is indicated by the sight-feed glass. By the use of the oiler, the feed at any point may be regulated.

Crank-pin Centre Oilers.—Fig. 60 shows the Nugent Patented Anti-stand, Crank-pin Oiler, manufactured by Wm. W. Nugent & Co., of Chicago.

This device provides a very efficient method of applying oil to the crank

A *B*

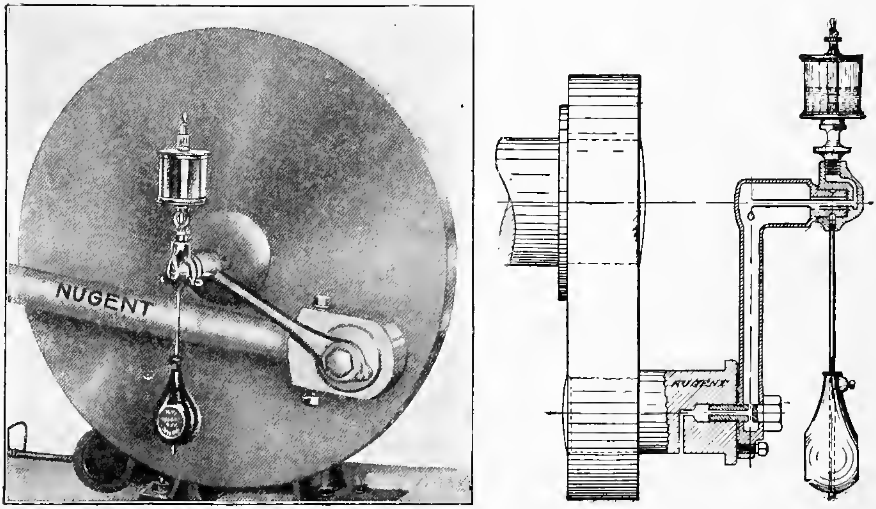


Fig. 60.—Nugent's anti-stand crank-pin oiler. *A*, outside view. *B*, sectional view.

pin and is positive in its action. The oil cup may be removed and a suitable open cup substituted, so that the crank pin may be supplied with oil from a continuous oiling system by feeding the oil from above.

As seen from the cut, the oil cup remains stationary and in an upright position during the revolutions of the crank, being located upon the same axis of rotation as the shaft.

Grease Cups.—Grease is usually fed by means of compression cups. The compression may be automatically obtained by a spring, or it may be produced by screwing down the piston by hand.

Fig. 61 shows a well-known type of Cross-head Pin Oiler and Top Guide Slide, made by the Wm. W. Nugent Company.

This type of device does away with the unsatisfactory "wiper cup," and insures a uniform supply of oil direct to the pin.

This cup type of telescope oiler, or, one connected to a circulating system, is of particular value for use on vertical engines, such as marine engines, for the lubrication of the eccentrics.

Usually the eccentrics of these engines are equipped with an oil boat, into which the oil is dropped from a stationary source. A large waste of oil occurs, due to the suction or air draft produced by the moving cranks, which draws the oil out of its course.

These oilers may be adapted for use on any reciprocating bearing, such as cross-head pins, double-disc crank pins, and eccentrics of steam engines.

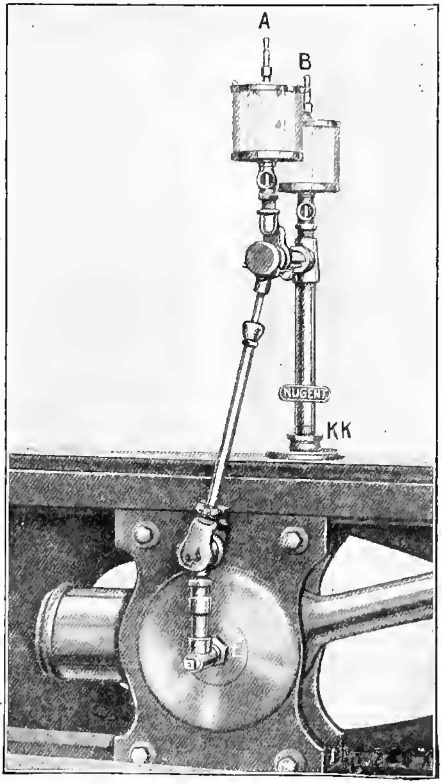


Fig. 61.—Cross-head pin and top guide oiler.

FILTERS AND FILTERING

Three Methods of Filtering Lubricating Oils.—There are three methods of filtering lubricating oils that are in general use; namely, capillary, pressure, and gravity filtration.

Filtering Operations.—There are two distinct operations to be performed during the filtering operation; namely, (*a*) the elimination of dirt and other impurities, and (*b*) the separation of any water that may have become mixed with the oil.

Requirements of an Efficient Filter.—The following general specifications should be used as a guide in the selection of a filter:—

(*a*) The filter should have large settling or precipitation capacity.

(*b*) The filtering medium should be easily and cheaply renewed.

(*c*) There should be sufficient area of the filtering medium exposed tc the oil.

(*d*) A strainer should be provided to strain the incoming dirty oil.

(*e*) The path of the oil through the filter should be as long as possible

(*f*) The entire area of the filtering medium should be subjected tc as nearly as possible an even pressure of oil.

(*g*) All handles and cocks of the filter should be well nickelled or other provision made for the prevention of rust.

(*h*) The body of the filter should be constructed of heavy-gauged metal.

Filtering Mediums.—There are a number of materials used for filtering mediums. The primary requirements of an efficient filtering medium may be enumerated as follows:—

(*a*) It should be easily removed for renewal.

(*b*) It should be easily cleaned, to allow for frequent replacement and cheap upkeep cost.

(*c*) It must not be too dense, or it will unduly retard or interfere with the flow of the oil through the filter.

(*d*) It should possess long life.

(*e*) It should filter efficiently.

The filtering mediums usually met with in general use are charcoal, animal bone dust, waste, asbestos, sacking, and specially-made filtering cloth.

By far the best and most serviceable filtering medium is cloth. Cloth does not offer too great a resistance to the flow of the oil. It can be easily cleaned, and any desired thickness can be obtained by using various numbers of layers.

Dense substances, such as charcoal, bone dust, etc., offer too great a resistance to the flow of the oil and produce extremely slow results. The removal of this dense type of filtering material is a tedious and difficult task, and requires that the filtering operation be stopped during the time of renewal of the filtering medium. Filter cloths can be easily and quickly replaced when necessary, without disturbing the continuous flow of the oil through the system.

Excelsior is sometimes found in use as a filtering medium in filters that are supposedly in the hands of experienced operating engineers. It is, however, one of the most unsuitable substances possible to obtain for this purpose, because, when oil is warm, it will absorb resin from the excelsior and soon will become thickened with a brownish mass, which will appear on the strainer cloths or sieves.

Filtering Cloth.—This cloth can be obtained in various textures to meet each condition of service, and by means of the ingenious methods adopted by the filter manufacturers a maximum "filtering area" can be obtained.

Dirty cloths, removed from the filter, may be washed and kept ready for instant replacement in the filter as occasion requires.

Process of Filtering.—The operation of a typical, efficient filter may be briefly described as follows:—

(*a*) The incoming oil containing impurities, such as water, dirt, metallic chips, etc., is first strained through a wire sieve or cloth strainer.

(*b*) It is then passed into the heating compartment. Here its gravity is reduced and the thinned oil is less able to retain water and solid matter. Usually steam is used to heat the oil, being carried through the compartment in a coil.

(*c*) Next, due time is given to allow the water and solids to be freed from the oil by passing it slowly over precipitation trays, or by other methods.

(*d*) The oil is then passed through the filtering medium to the clean oil compartment.

Gravity Filtering.—Fig. 62 shows a well-designed type of gravity filter as manufactured by the Pittsburgh Gauge and Supply Company, of Pittsburgh, Pa.

The operation of this type of filter may be described as follows: The dirty oil enters through the screen (*B*) into the settling tank (*A*), and is then passed through the valve (*C*) into the funnel (*D*) and into the central compartment. The funnel (*D*) is provided with a screen, and, at the lower end, with a perforated conical foot (*E*), closed at the bottom.

The central chamber is partially filled with water and is kept at a moderate temperature by the steam coil (*I*). The dirty oil descends through the funnel tube and is discharged below the surface of the water at the foot of the tube.

When the level of the oil reaches the outlets (*J*), (*J*), it flows through into the filtering cylinders (*KK*), formed of open-wire mesh and wrapped with several layers of filtering cloth. Passing through this filtering medium, it is then collected in the main storage tanks (*L*) and is ready for use.

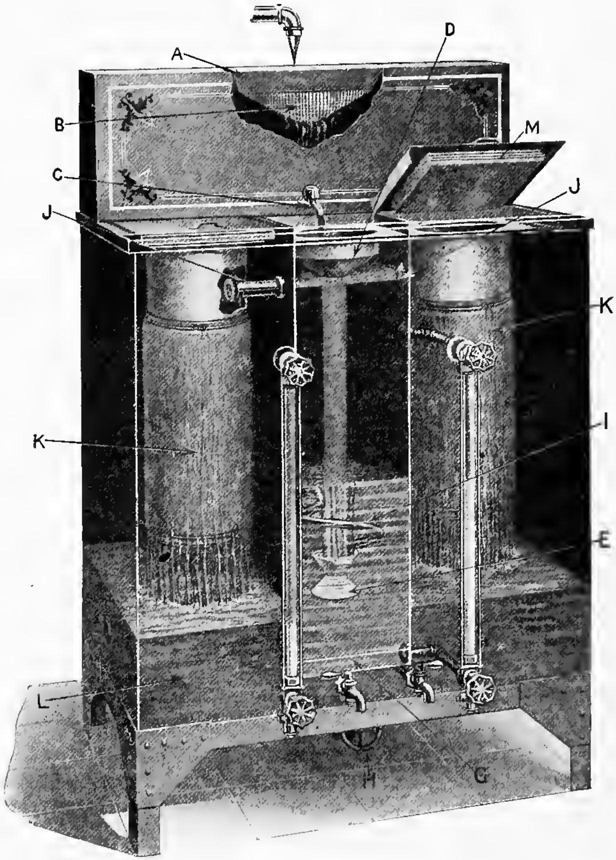


Fig. 62.—Gravity oil filter made by the Pittsburgh Gauge and Supply Company.

Fig. 63 shows a gravity filter manufactured by The S. F. Bowser & Co., Inc., of Fort Wayne, Ind.

The flow of the oil in this type of filter is indicated by the directing arrows in the figure. This type of filter makes use of the precipitating tray principle, which is very efficient.

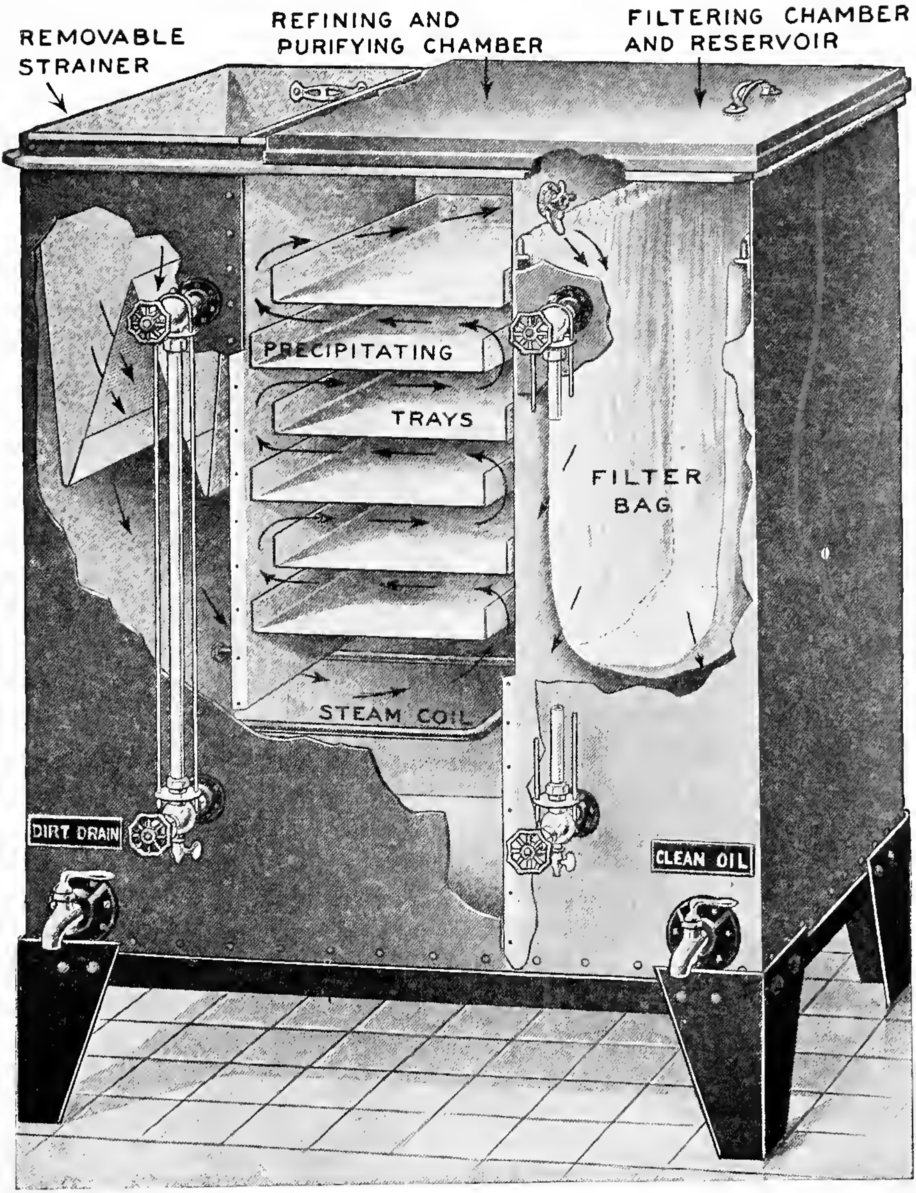


FIG. 63.—Gravity oil filter, made by S. F. Bowser & Co.

Fig. 64 shows an isometric view of a Peterson Power Plant Oil Filter. The filtering and purifying operation of this filter may be described as follows: The dirty oil is put into the filter through the strainer box (1),

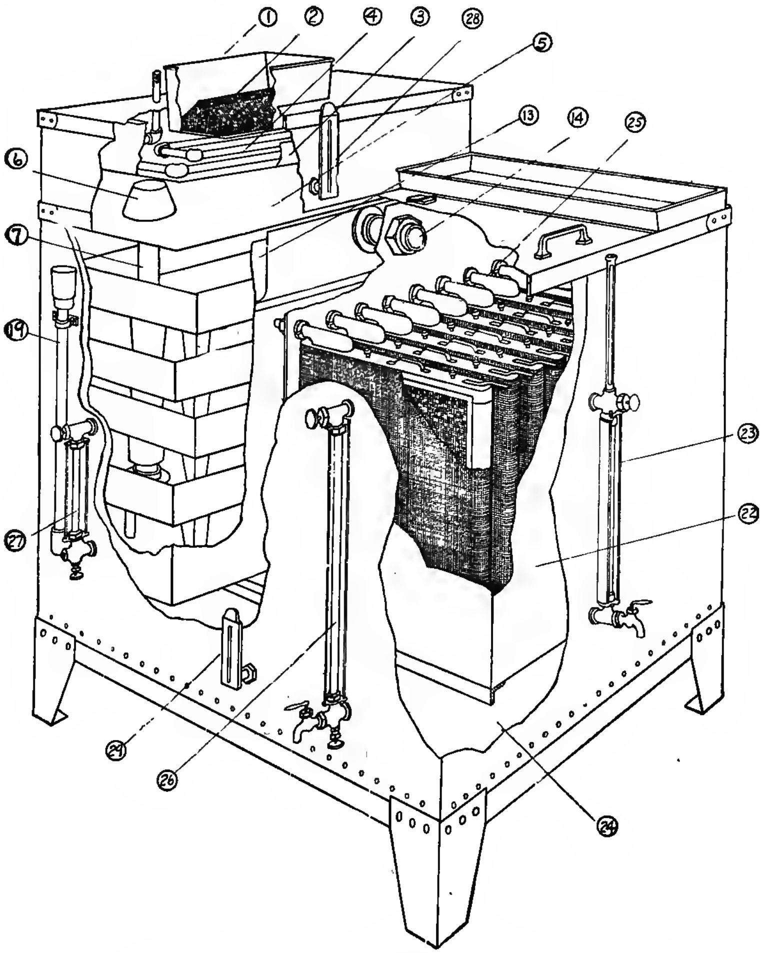


FIG. 64.—Peterson power plant filter, showing interior construction.

and passes down through the strainer (2), which is designed to remove any large particles of waste that may be in the oil. The oil is then passed to the warming tray (3), which contains the heating coil (4), and then passes consecutively through the compartment (5), funnel (6), pipe (7), and over the baffle (8) (see Fig. 65), under the bottom tray (9).

The oil is then passed in a zigzag course upward over the trays (9), (10), (11), and (12), and out through the opening (14) to the filtering compartment. (The rated capacity of the oil in passing over the trays is 0.7 foot per minute, and the manufacturers claim that the slow passage of the oil greatly increases the settling efficiency of the filter.) The separated water is drawn off from the trays by the funnels (15), (16), (17), and (18).

The filtering compartment contains a number of filtering units, which are made of heavy galvanized screen wire, the sides being separated one inch and covered by a bag-shaped filtering cloth that is slipped over each unit.

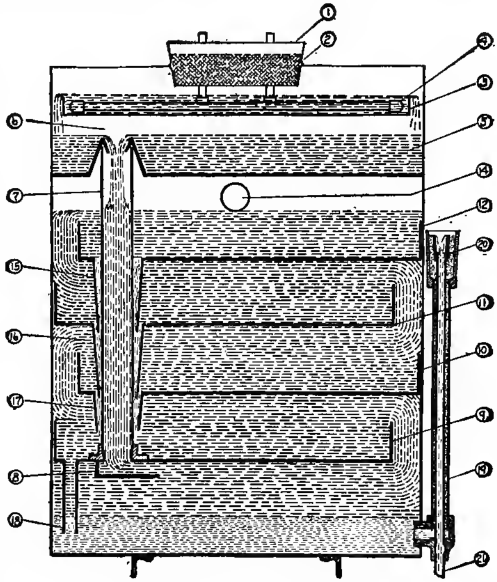


FIG. 65.—Section through the precipitation compartment of a Peterson power plant filter.

The oil passes from the outside to the inside of the filtering units, then out through the nozzles (25) into the clean oil compartment.

Filter Notes.—Some filters are in use which depend upon the capillary action of the filtering medium. The oil is siphoned from the dirty oil compartment to the clean oil compartment by the use of wicking. The dirt and impurities which may be in the oil are intended to be left in the wicking.

Generally, oil filters are equipped with steam pipes, so that the body of the oil may be reduced in order to facilitate precipitation of the impurities held in suspension in it. The steam supplied to this coil should never be taken from live steam mains, for, while good results can be obtained by moderately heating the oil to a temperature of 130° to 150° Fahr. with exhaust steam, excessive heating will tend to destroy the lubricating qualities of the oil.

The Care of Filters.—Careful attention must be paid to the systematic and frequent cleaning of oil filters. Especially is this true for filters used in continuous oiling systems.

When the dirty filter medium is removed from the filter, the sediment at the base of the filter must be removed. Many careless "oilers" allow this sediment to collect for some time, and so long as it is held largely in suspension between the water and oil layers it increases rapidly and will soon work up into the oil and cause poor filtering results.

Sudden hot bearings, occurring at several points in the engine-room, should always immediately result in an examination of the filter.

Filtering Factor of Safety.—The factor of safety for the capacity of the filter should always be considered when purchasing or specifying a new filter for use in a circulating system. Under-capacity of the filter is the cause of many hot bearings, which are unjustly blamed upon the circulating system as a whole, or upon the oil used.

When using Table 23, which gives the approximate filtering capacities required for various horse-powered engines, a factor of safety of 20 to 40 per cent. should be used to determine the proposed filtering capacity.

For large bearings, running at medium speeds, allow 4 to 5 gallons of oil per square foot of projected bearing area.

Usually about 2½ to 3½ gallons of filtering capacity per hour for each 100 H. P. for simple engines up to 175 R. P. M. will be sufficient. For compound engines 4¼ to 4¾ gallons per hour for each 100 H. P. will give a satisfactory capacity for the oil filter.

Tandem engines should be rated as outlined above for simple engines, with the result multiplied by two.

For engines running above 175 R. P. M., the capacities as indicated above should be increased by about 25 per cent.

CHAPTER XIII

OIL-HOUSES AND OIL-HOUSE METHODS

MANUFACTURING establishments, which use large quantities of oil should provide a central oil storage. The oil-house should be placed in charge of a competent man, who will keep a careful and accurate account of the oils issued to the various departments of the plant. By examining the oil records monthly, and noting the increases or decreases in the amounts of oil used by the various machines, a close check may be maintained upon the efficient and economical operation of the plant, and large savings may be effected in the annual cost of lubrication.

In large works, where the oils are received in tank cars, or where the

FIG. 66.—Oil storage outfit made by the Gilbert & Barker Manufacturing Company.

oil is received in barrels in carload lots, the oil-house should be equipped with a railroad siding, to facilitate the discharge and proper handling of the oil shipments without delays and losses.

For barrel delivery, the receiving platform should be on a level with the freight car floor, and provision should be made in the size of the platform to receive a carload at one time. (A minimum carload consists of 65 barrels.)

For tank car delivery, suitable unloading pipes must be laid to a point or points near the track. It is well to locate these unloading points or outlets to one side of the receiving platform, so that freight cars containing barrel oil may be unloaded without interfering with the tank car shipments.

If possible, the oil-house should be centrally located in the grounds of the plant, with a view towards efficient distribution of the oil.

Fig. 66 shows a storage tank outfit manufactured by the Gilbert & Barker Manufacturing Company, of Springfield, Mass. It is designed for location on the floor of the oil-house, and does not require any underground tanks. It is equipped with a barrel track, cradle, and chain hoist, to provide convenient methods for emptying oil barrels by gravity.

Fig. 67 shows a Folding Barrel Skid and Drainer made by The Gilbert & Barker Manufacturing Company. It provides an easy and

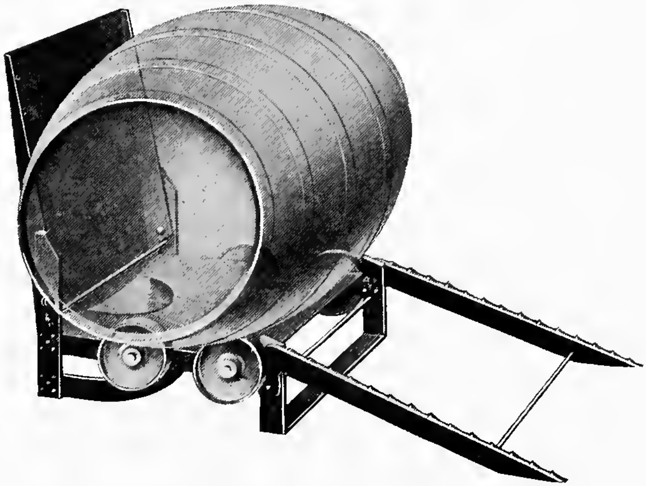


Fig. 67.—Folding barrel skid and drainer, made by the Gilbert & Barker Manufacturing Company.

effective method of emptying oil barrels by gravity, which is the method that gives the best results. If the oil is heavy, it is impossible to thoroughly drain the barrel by pumping out the oil, and usually a waste results, due to oil remaining in considerable quantities on the insides of the barrels.

Empty Oil-barrel Storage.—A suitable storage place should be provided for empty oil barrels at the side of the oil-house.

Empty barrels should always be stacked on their bilges, with their bungs down. They should be returned at various times in carload lots, to the oil company, so that credits may be received for their market value.

As deductions are made by the oil company for barrels not returned in good condition, it is advisable that care be taken not to damage the heads

and staves. The bung-holes should not be bored out to an increased diameter, as that will result in "dockage."

When removing the bung use a small chisel or a bung pick, and do not try to knock the bung into the barrel, as this practice is liable to split the stave. If a vent is necessary, make it small. Never use a faucet that will not screw into a 1¼-inch hole.

Store empty barrels under shelter, if possible, to prevent the inflow of rain-water, which dissolves the glue and fouls the barrel.

Oil-house Records and Costs.—The various departments of a plant should be charged with the amounts of the different oils used.

When a man requisitions oil from the oil-house, a slip should be filled out, showing the grade and the amount of the oil issued and the man and department getting it. A specimen slip, which may be used as a guide, is shown below:

Oil-house Requisition Slip

DATE		DEPARTMENT	
HOUR			
NAME OF OIL	....	Gallons	....
" " "	....	"	....
" " "	....	"	....
NAME OF GREASE	....	Pounds	....
Foreman:	....	Issued to	....

At the end of the day or week, as desired, a report may be prepared upon a suitable form, by the oil-house man, showing exactly the total gallonage of oils and poundage of greases that have been issued to the various shops and the stock remaining on hand. Four carbon copies of this report should be made. One copy is sent to the purchasing agent, so that he may be advised when and how often to order. One copy should be sent to the accounting office, so that a record of deliveries may be had, giving the time and amounts, which will aid this office in properly checking the oil company bills. One copy should be sent to the general manager's office, so that this office may keep an exact record of the cost of lubrication of the plant and may also note the relative amounts of oils used by the different shops, with a view to correcting any apparent waste.

The report should include a suitable record of deliveries and number of empty barrels returned to the oil company, so that the stock on hand may be clearly indicated. The sample report given below is included as a suggestion to those desiring to install a similar system to that described

above. The weight method of checking deliveries from the oil company should be used in all cases, and is described in another section of this book.

(SPECIMEN REPORT)

Weekly Oil-house Report of the Euraka Shipbuilding Company

Date From................ Date To................

Name of oil or grease	Issued to								
	Yard	Machine shop No. 1	Machine shop No. 2	Power house No. 1	Power house No. 2	Auto trucks	Cranes	Tool house	Total
Cylinder oil, No. 1.....	..	...	...	75	65	...	..	..	140
Cylinder oil, No. 2.....	..	...	...	53	..	...	..	90	143
Machine oil, No. 1.....	..	157	235	75	56	...	..	..	523
Machine oil, No. 2.....	..	67	35	25	35	...	20	50	212
Black oil..............	35	10	...	..	..	...	65	..	110
Motor cylinder oil.....	..	...	...	..	..	38	..	..	38
Gasoline..............	75	...	...	..	..	175	..	35	285
300° Mineral seal oil...	30	...	...	..	..	...	..	..	30
150° Burning oil.......	64	...	...	..	..	...	..	25	89
Cup grease............	..	10#	25#	..	10#	...	5#	..	50#
Gear grease...........	25#	...	25#	..	..	...	10#	..	60#

Stock Record

Name of product	On hand at beginning week	Used during week	Received during week	Stock on hand
Cylinder oil, No. 1................	235	140	154	249
Cylinder oil, No. 2................	258	143	152	267
Machine oil, No. 1................	650	523	750	877
Machine oil, No. 2................	365	212	357	510
Black oil.........................	150	110	250	290
Motor cylinder oil................	75	38	...	37
Cup grease........................	147#	50#	...	97#
Gear grease.......................	75#	60#	378#	393#
300° Mineral seal oil..............	75	30	...	45
150° Burning oil..................	175	89	50	136
Gasoline..........................	575	285	250	540

Empty Barrels Returned for Credit

Kind of barrels	Number	Date returned	Credits at current prices	Totals
Refineds..........................	8	1/17	$1.05	$8.40
Machine, motor oil and cylinder oil barrels..........................	26	1/17	0.95	24.90
Black oil barrels..................	5	1/17	0.85	4.25

Report signed by...................

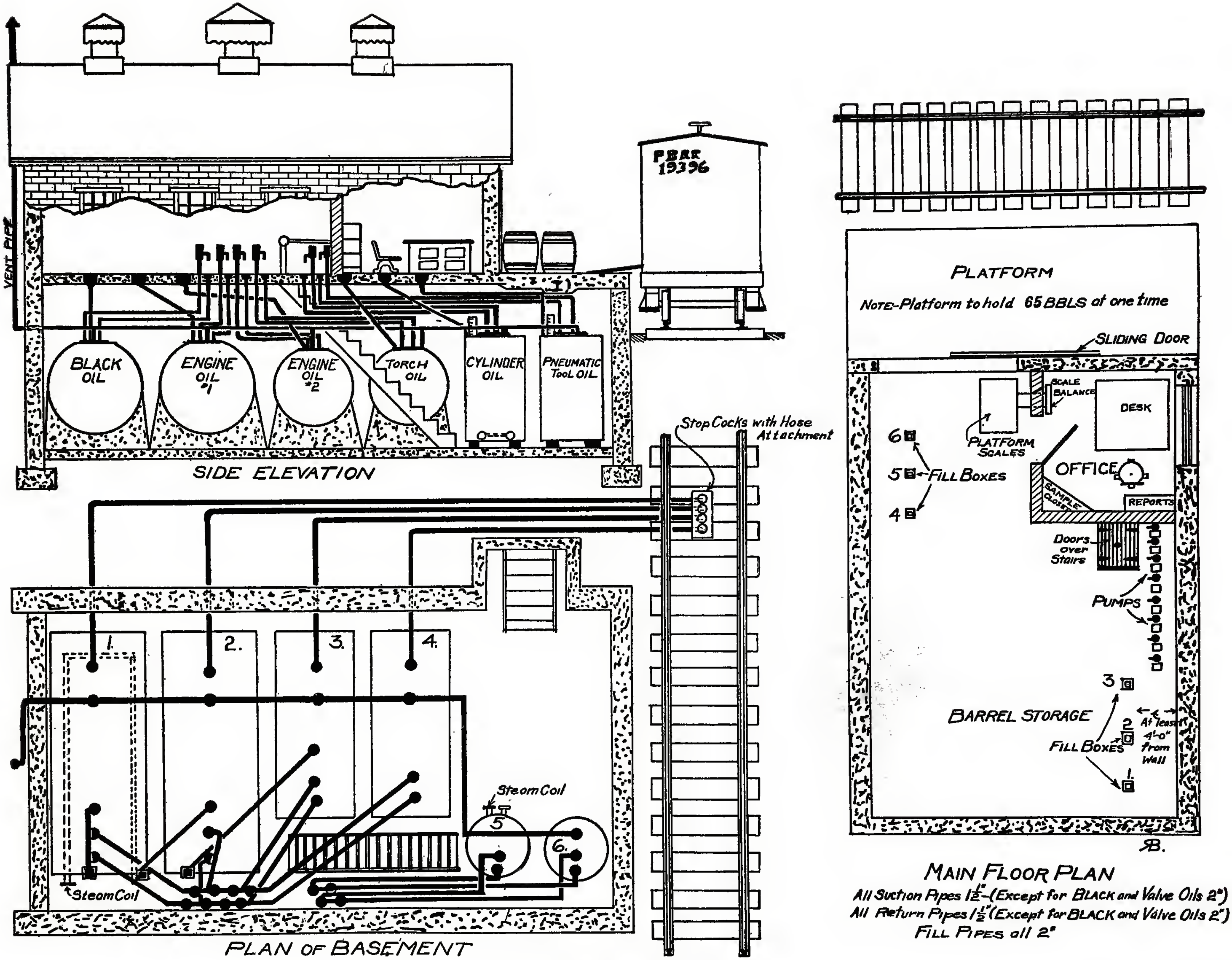


FIG. 68.—Oil-house for a large plant.

Delivery Forms.—The following form is suggested for use as a record of delivery of oils to the oil-house in barrels, when the weight method is used for checking the gallonages:—

Delivery Form

BRAND................DATE DELIVERED............DATE TESTED.................

WEIGHT BARREL AND OIL..........(gross weight). GRAVITY AT........FAHR.........

WEIGHT BARREL ....(tare weight). CORRECTED GRAVITY...............

NET WEIGHT OIL................(pounds). WEIGHT PER GALLON.......AT 60° FAHR.

$\frac{\text{WEIGHT OIL}}{\text{WEIGHT PER GALLON}}$ = ...GALLONS OIL DELIVERED.

....................GALLONS BILLED BY OIL COMPANY.

....................GALLONS ADJUSTMENT.

CHECKED BY..................

The above form can be gotten up as a small and compact pad, so that the checker can take down the readings direct as he checks the delivery.

The Design of the Oil-house.—As a suggestion in laying out an oil-house for the average large plant, the plan and elevation drawings of a well-planned building for this purpose are shown in Fig. 68.

The oils are stored in the basement as shown, and are brought up to the main floor by means of pumps provided with suitable returns for excess oil. The tanks are each connected to a vent pipe.

For filling the tanks, the oil may be brought in tank cars or barrels, provision being made for emptying the tank cars through pipes laid out to the middle of the track, and for emptying barrels by the use of the fill boxes on the main floor of the house.

The black oil and cylinder oil tanks are equipped with steam coils to thin the oil and aid its flow when pumped.

The unloading platform is capable of carrying 65 barrels at one time, which is a minimum carload.

Platform scales are placed at the entrance, to check all barrel deliveries, and a suitable sample case is located in the office, in which samples of the incoming shipments may be kept for reference purposes.

The house should be constructed as nearly fireproof as possible, and the ventilators in the roof kept in good working condition.

The tanks should be connected to a vent, as shown.

CHAPTER XIV

THE STEAM ENGINE INDICATOR AND ITS USE

THE steam engine indicator may be described as being a recording pressure gauge, which is designed to be attached to the cylinder of an engine and connected by suitable means to the cross-head, so that a curve may be drawn to scale, on a sheet of paper, which will represent the pressure within the cylinder at the various parts of the stroke of the piston.

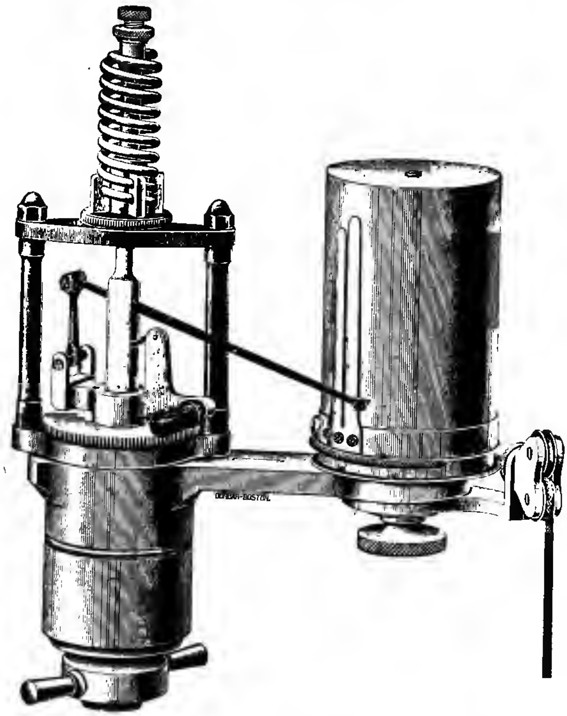


FIG. 69.—Outside view of Crosby steam engine indicator.

The essential parts of an indicator are as follows: A cylinder, in which is a movable piston, whose movement is resisted by the compression of a calibrated spring. The relative movement of the piston is transferred by a system of small levers to the "pencil arm." The pencil arm carries

at its extremity a small piece of writing lead, which may be pressed against the paper carried on the "drum." The drum is made to rotate in a relative motion, with the travel of the piston in the cylinder, by means of an indicator cord, which is attached to a suitable reducing gear, that receives and reduces the motion of the cross-head.

The indicator is connected by a steam passage to the interior of the

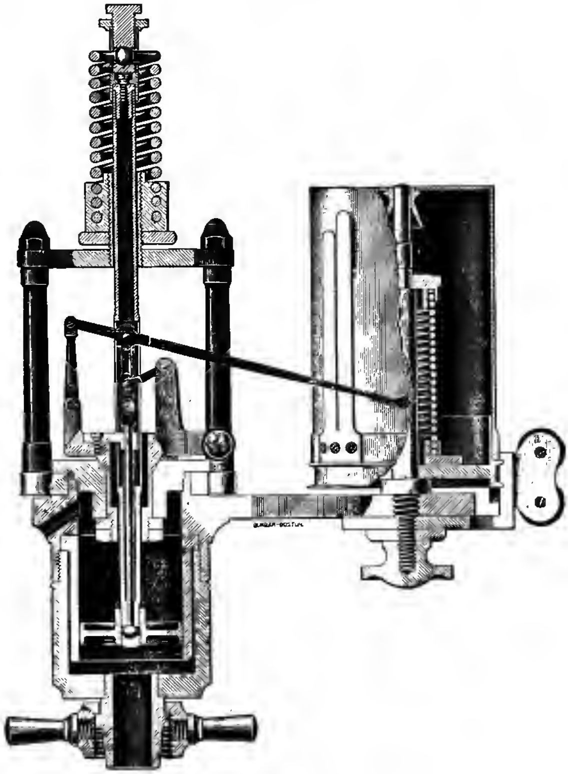


FIG. 70.—Sectional view of Crosby steam engine indicator.

engine cylinder. Thus it can be seen that the curve or diagram drawn by the indicator is a record of the pressures in the engine cylinder at the various parts of the piston stroke. Fig. 69 and Fig. 70 show an outside and sectional view of the Crosby Outside Spring Indicator.

A typical diagram, obtained by the steam engine indicator from a single-cylinder, slide-valve engine in good condition, is shown in Fig. 71. The action of the engine valve may be interpreted from the indicator

diagram as follows: The steam valve is opened at 6, and the line 6–1 is called the "admission line." From 1–2 the steam valve is open and the piston is moving out on its stroke. At 2 the steam valve is closed; this point is called the "cut-off." The steam is then expanded in the cylinder as the piston moves out. At 5 the exhaust port is opened and the pressure falls; this point is called the "release point."

The line 3–4 is called the "exhaust line" and shows the drop in pressure due to the open exhaust valve. The piston, now having arrived at the end of its stroke, starts back. The line 4–5 is "the back pressure line." The piston is now pushing the spent steam out of the exhaust port. At 5 the exhaust port is closed and the steam remaining in the steam cylinder

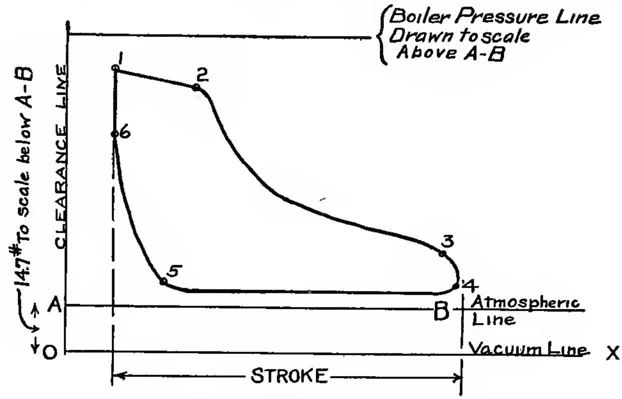


FIG. 71.—Typical indicator diagram.

is compressed, acting as a cushion to absorb the inertia of the moving parts. The pressure rises, due to compression, until the point 6 is reached, when steam is again admitted to this end of the cylinder by the uncovering of the steam port by the valve. The cycle of events is then repeated for this end of the cylinder.

The cycle of events just described occurs alternately in both ends of the cylinder. These ends are called the "head" and "crank" ends, respectively. There will be a separate card for each end of the cylinder. These cards are usually taken on the same sheet of paper, so that the record will be complete on one sheet. The line O–X is the "vacuum line" and is drawn to scale, 14.7 degrees below the atmospheric line.

Mean Effective Pressure.—It should be evident, that if the mean height of the indicator diagram, in hundredths of an inch, is obtained, and the

"scale of the spring," which is the number of pounds required to compress the spring one inch, is known, the mean effective pressure developed during that stroke can be obtained. For the head end of the cylinder this "mean effective pressure" per square inch, multiplied by the area of the piston in square inches, will give the total force acting on the piston at that end during that stroke. For the crank end of the cylinder a reduction of the effective area of the piston is produced by the area absorbed by the piston rod; therefore, the area of the piston in square inches, minus the area (cross-section) of the piston rod, multiplied by the mean effective pressure for that end, will give the total force acting on the piston at that end for that stroke.

By multiplying the mean value of the crank end and head end total forces by the number of feet travelled by the piston per minute, the foot-pounds of work done per minute are obtained.

"**Horse-power**" is the rate of doing work at 33,000 foot-pounds per minute. Therefore, if—

P = Mean effective pressure, = mean height diagram (inches) $\times$ spring scale.
A = Area of the piston (effective) in square inches.
S = Speed of the piston in feet per minute.

Then the horse-power developed by a single cylinder engine will be:—

$$\text{H. P.} = \frac{P \times A \times S}{33{,}000} \text{ or: H. P.} = \frac{P \times L \times A \times N}{33{,}000};$$

where P = M. E. P.
L = Length of stroke in feet.
A = Effective area of piston in square inches.
N = Number of strokes per minute, which is twice the number of R. P. M.

Indicated Horse-power.—The horse-power obtained with the aid of the indicator is called the Indicated Horse-power of the engine. (I. H. P.)

Brake Horse-power.—To obtain the power output at the fly-wheel of the engine, the Brake Horse-power must be determined. (B. H. P.)

Mechanical Efficiency.—The mechanical efficiency of an engine is the ratio $\frac{B.H.P.}{I.H.P.}$ and is of value in demonstrating the efficiency of engine lubrication.

Method of Obtaining the Brake Horse-power.—The brake horse-power of an engine is the rate of delivery of energy from the fly-wheel of the engine. It is measured by means of a dynamometer, which may be one of several types.

The most common form of dynamometer is the Prony Brake.

The form of a typical Prony Brake is shown in Fig. 72. The operation of this apparatus is as follows: *H* is the fly-wheel of the engine, turning as indicated by the arrow. The lever *A* rests on the wheel *H* as shown. *K* and *L* are wooden blocks, which are pressed against the

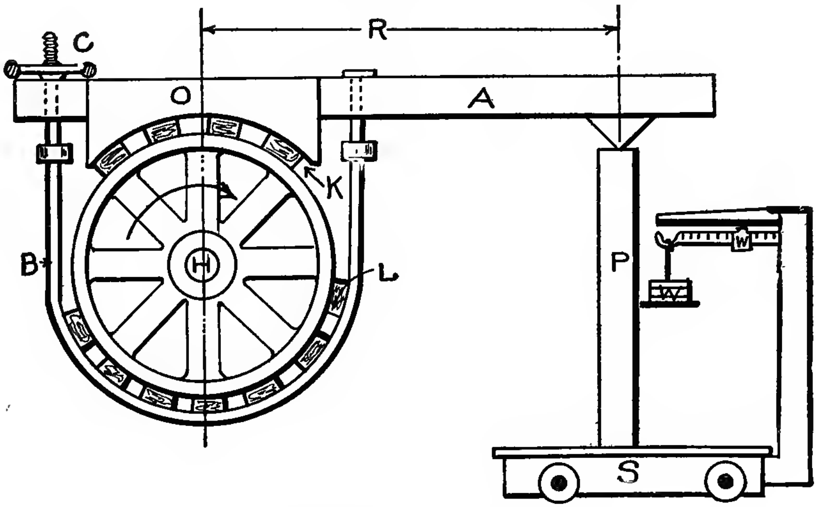


FIG. 72.—Outline drawing of a Prony brake.

face of the fly-wheel by the tension produced by the adjustable strap *B* and the weight of the yoke *O*, thus applying a friction load to the fly-wheel as desired. The pressure, due to the energy absorbed by the brake, is carried by the lever *A* and post *P* to the platform scales *S*, which are adjusted to just balance the load.

If $R =$ Length of the brake arm or lever R in feet.

$N =$ Revolutions per minute of the fly-wheel.

$W =$ Weight in pounds at distance R, as measured by the scales S.

Then the brake horse-power would be: $\frac{2\pi RNW}{33{,}000}$

$2\pi R$ is the circumference of the circle that would be travelled by the end of the brake lever if it could turn. π is 3.1416.

The value $\frac{2\pi R}{33{,}000}$ is called the "brake constant" and is the same for all loads, when using the same brake.

Before starting the run, a "zero reading" of the brake must be taken, since the scales weigh not only the pressure due to the friction load on the lever, but also the weights of the brake and post P These weights must be determined and subtracted from all of the readings of the scales during the test, to obtain the net weights.

To determine the zero reading, the strap B is loosened and the fly-wheel is turned by hand in one direction and the weight registered on the scales is noted. Then the fly-wheel is turned in the opposite direction and the weight registered by the scales is again noted. The friction between the loosened brake band and the fly-wheel is assumed to be the same for either direction of fly-wheel rotation. In one case, therefore, the friction load of the brake itself is added to the combined weight of the brake lever and post, while, when the direction of the rotation is reversed, the friction load is deducted from the weight of the lever and post. By adding these two weight readings together, and dividing the result by two, the mean weight of that part of the prony brake which rests upon the scales is determined. This value is called "the brake zero."

LUBRICATING TESTS WITH THE ENGINE INDICATOR

As a means of illustrating a typical method of using the steam engine indicator to demonstrate the relative efficiencies of two shafting oils, the following assumed conditions are used, and the test is written up in the approved form:—

Report of Friction Test

DATE (3-1-16). MADE AT (ROYAL MFG. CO.)
BY (C. J. BROWN). RESULTS CHECKED BY (J. B. SMITH, PLANT ENGINEER)

Purpose of Test.—To compare the relative efficiencies and economies of two shafting oils, designated as Oil No. 1 and Oil No. 2.

Oil No. 1 costing .... 18 cents per gallon
Oil No. 2 costing .... 16 cents per gallon

Operation.—The mill was operated with all shafting running and with all machines "thrown off." No. 2 oil was supplied to all of the cups and feeds in just sufficient quantities to keep the bearings normally cool.

When the conditions were normal, a series of indicator cards were

taken. When these cards were measured, it was found that the engine was developing 210 H. P. at 100 R. P. M.

The shafting was now stopped and the bearings were flushed out with kerosene, so that none of them contained any residue of oil No. 2.

Oil No. 1 was now placed in the oil cups and the shafting and engine were operated at as near the same running conditions as those which prevailed during test No. 2 as it was possible to obtain.

A series of indicator cards were taken and, when measured, showed that, when using oil No. 1, the power developed by the engine, when making 100 R. P. M., was 203 H. P.

It was estimated that in this plant the cost of an indicated horse-power per year was $35.

The oils were given a quantity test, by lubricating the shafting bearings with each oil for a period of one week, using just enough oil to keep the bearings running cool. The results of this test were as follows:—

112.3 gallons of oil No. 2 and 96.5 gallons of oil No. 1 were required per week.

Summary of the Test.—

Cost of Oil No. 2:

112.3 × 16 = $17.97 per week. 17.97 × 52 = $934.44 per year. (210 – 203) × 35.00 = $245.00 (cost of the excess friction load).

Total Cost of Lubrication Using Oil No. 2: $245.00 per year
934.44 per year

$1179.44

Cost of Oil No. 1:

96.5 × 18 = $17.37 per week. 17.37 × 52 = $903.24 per year. Deducting the cost of the (7) horse-power saved per year and valued at $245.00—

Total cost of lubrication, using oil No. 1.................... $903.24
245.00

$658.24

The saving when using oil No. 1 is......................... $1179.44
658.24

$521.20

NOTE.—This amount seems to be large to those who have not come into contact with tests such as the one outlined above, but the author can assure the reader that this is a very conservative result, and that similar scientific tests conducted in the average mill will produce even more surprising results.

CYLINDER OIL TESTS WITH THE INDICATOR

A typical test to compare the efficiencies and economies of two cylinder oils is outlined as follows, assumed values being used as a method of demonstration. The following outline is the proper form in which these tests should be written up:—

Friction Test

DATE (4-10-16). MADE AT: (AJAX LOCOMOTIVE CO.)
BY (H. B. JONES). CHECKED BY: (B. B. BROWN, PLANT ENGINEER)

Purpose of Test.—To compare the relative efficiencies and economies of two cylinder oils, designated as oil *A* and oil *B*, oil *B* being in present use:—

Oil *A* costing .... 35 cents per gallon
Oil *B* costing .... 33 cents per gallon

Conditions.—The engine is a slide-valve type, direct connected to a dynamo. The normal running speed is 130 R. P. M. The bearings of the engine are flood-lubricated, and those of the dynamo are ring-fed.

Operation.—The engine was run at full normal speed, with dynamo carrying no load.

Cylinder oil *B* was fed to the cylinder at the rate of five drops per minute, which had been found to be the minimum feed for this oil to prevent signs of distress in the cylinder.

A series of indicator cards was taken, which, when measured, showed that the engine was developing 23.5 H. P.

The engine was run for three hours with no cylinder oil, and at the expiration of this time the lubricator was emptied of oil *B*, and oil *A* was substituted.

The running conditions were again maintained as near as possible to those prevailing when testing oil *B*.

After running with oil *A* for one hour, to permit a film of this oil to become thoroughly spread over the surfaces of the cylinder and valve, and feeding five drops of oil per minute, a second series of indicator cards was taken. When these cards were measured, it was found that the horse-power developed was 18.

The feed of oil *A* was now reduced until the cylinder showed signs of distress, when the feed was increased until the conditions returned to normal. It was found that normal running conditions could be maintained when feeding four drops of oil *A* per minute. A series of indi-

cator cards was taken and showed that the horse-power developed had not been increased by the reduced feed, but remained at 18.

Summary of Test.—

Oil *B* fed at five drops	23.5 H. P.
Oil *A* fed at four drops..................................	18.0 H. P.
	5.5 H. P.

Oil *A* fed at four drops per minute, saved one drop per minute over the consumption of oil *B*. Therefore:

$60 \times 24 = 1440$ drops per day. Assuming 4500 drops of oil to the quart, which is a conservative figure, and four quarts to the gallon, $\frac{1440 \times 365}{4500 \times 4} = 29.2$ gallons saved per year, using oil *A*.

Total Cost of Lubrication, Using Oil B:

Three and one-half barrels of oil *B* used in the past, per year, would be: $3.5 \times 50 \times 33 = \$57.75$, cost of oil *B*.

Five and one-half excess friction horse-power will cost: Assuming $50 per horse-power per year, which value includes fuel, attendance, fixed charges, depreciation, etc.:

$$5.5 \times 50 = \$275.00 \text{ per year.}$$

Therefore the total cost of lubricating with oil *B* will be:—

$$\begin{array}{r} \$57.75 \\ \underline{\$275.00} \\ \$332.75 \end{array}$$

Total Cost Lubrication, Using Oil A:

Deducting the saving in gallonage,

$$((3.5 \times 50) - 29.2) \times 35 \text{ cents} = \$51.03.$$

Subtracting costs of oils, and adding cost of friction H. P. ($\$57.75 - \$51.03) + \$275.00 = \$281.72$, saved in one year, by using oil *A*, even at an increased price of two cents per gallon, over the cost of yearly lubrication, using oil *B*.

The Value of Tests.—It is not uncommon to find conditions similar to those described in the cylinder oil test preceding. Oil engineers, working in conjunction with the operating engineer, can produce some very interesting results, by similar tests. It will be surprising to the operating engineer, who thought that his engine cylinders were receiving efficient lubrication because there was no apparent sign of cylinder cutting or distress, to learn how much money may be saved in operating cost by scientific lubrication.

PART IV

CHAPTER XV

AIR COMPRESSORS AND THEIR LUBRICATION

AIR compressors are usually of the single-cylinder, or of the two-cylinder, two-stage type. In the single-cylinder type, the air is compressed to the full desired degree of compression in one cylinder, while in the two-stage type, the compression of the air is broken. In the latter type, it is usually compressed to 40 or 50 pounds per square inch, in one cylinder, and then it is passed through an intercooler, where its temperature is reduced before the compression occurs in the second cylinder, in which cylinder the compression is completed.

The series of operations described for the two-stage compressor may be also carried out in further detail, in the three- and four-stage compressors, the air being compressed a small amount in each cylinder and then cooled and further compressed in the next.

Tables of Temperatures.—When air is compressed, the work which is consumed in the compression is converted into heat and is evidenced by the rise in temperature of the compressed air. This rise in temperature of the air follows a definite law, and the theoretical temperatures can thus be tabulated.

TABLE 25

TEMPERATURE OF AIR AT INLET 60° FAHR.; PRESSURE OF THE AIR AT INLET IS ATMOSPHERIC

Temperature in degrees Fahr.	Gauge pressure pounds	Temperature in degrees Fahr.	Gauge pressure pounds
145	10	485	100
178	15	540	125
234	25	589	150
339	50	672	200
420	75		

The heads and cylinders of compressors are usually water-jacketed, in order to prevent the compression heat from becoming excessive, which would reduce the economy of operation of the machine.

The use of intercoolers also reduces the heat of compression retained in the air. Therefore the temperatures given in the table are not actually

met with in practice, but may serve as a guide to the mechanical and physical conditions that are met with in air-compressor lubrication.

Lubrication of Air Cylinders.—The lubricating requirements of air-compressor cylinders differ from the lubricating requirements of steam-engine cylinders, in that there is no moisture present. There is the intense dry heat of compression to be dealt with, however, and this heat has a tendency to reduce the body of the lubricant and to vaporize it.

For compressions up to 125 pounds per square inch, an oil having the following approximate specifications is recommended: (270 Vis. at 100° Fahr. and 420° Fahr. flash, P. B.) (350 Vis. at 100° Fahr. and 375 or more flash, A.B.). Air-compressor oil must have a good evaporation test and should be filtered. For high pressures, an oil having the following characteristics should be used: (320 Vis. at 100° Fahr. and a flash test of 525 or over, P. B.) (750 Vis. at 100° Fahr. A. B.).

The cylinders and valve chests of air compressors must be sufficiently cooled to avoid explosions due to air that may be carburetted with oil.

A striking illustration of the effect of the heat of compression of air is shown in the Diesel Motor, where air is compressed to about 450 pounds per square inch and is then hot enough to ignite an atomized charge of the heaviest oil.

Air-compressor oils must be straight mineral oils and must not be too high in viscosity. They should be examined as to the nature and amount of the residue left after evaporation.

For compression temperatures of 350° Fahr. to 400° Fahr. the oil used should not flash below 500° Fahr., and where the temperature does not exceed 300° Fahr. an oil of not lower than 400° Fahr. may be used.

When feeding lubricating oil to air-compressor cylinders, care must be taken not to feed an excess of the oil, which will result in gumming and carbon-forming deposits.

Dusty and impure air, if supplied to compressor cylinders is often the cause of cylinder deposits. The location of the air inlet should always be first examined, when adjusting a compressor complaint.

Most cases of air-compressor complaints come from the users of small, single-stage machines, and the trouble is usually due to excessive temperatures, caused by forcing the machines. Compressors having mechanically operated valves require more oil, but cause less trouble than compressors having spring valves. Trouble with multistage compressors is not usual.

The air in these machines rarely ever attains an extremely high temperature, unless the cooling water system becomes deranged.

Receiver Pipes.—The "receiver" and pipes into which the compressor discharges, should be blown out regularly, to remove any oil and water that may have accumulated there.

Discharge Valves.—The discharge valves should be regularly inspected. Often cases have been investigated where the discharge valves have stuck and admitted hot compressed air back from the receiver into the cylinder. The resulting increased temperatures of the air before compression starts, causes it to reach the flash-point of the cylinder lubricating oil during compression.

Lubricators.—Always close the lubricators immediately before the compressor is shut down.

Oil Feed.—Reduce the amount of oil fed to the compressor cylinder to a minimum. An excess of oil, as before stated, not only causes carbonizing troubles, but offers a sticky resting place for dust entering with the air, thus causing cylinder and exhaust-valve troubles.

Cylinder Deposits.—Cylinder deposits may be removed by feeding ordinary soapsuds through the regular oil-cup hole for several hours, while the machine is running. Before the machine is shut down, stop feeding the soapsuds and commence feeding oil, to avoid rusting.

CHAPTER XVI

AUTOMOBILE LUBRICATION

Various Types of Lubricating Systems.—Lubricating systems for the standard makes of motor cars may be divided into several distinct types, namely: Forced Feed, Splash Feed, Combination Force and Splash Feed, and various combinations of the above types with separate feeds or pumps.

A typical type of motor lubricating system is shown in Fig. 73 and is described as follows:—

The crank-case and fly-wheel pit is used as a reservoir for the oil, which is put into it up to the level of the upper cock *B*. The fly-wheel *C* dips into the oil, as shown, and whirls it up against the top of the fly-wheel case and also out into the crank-case, spraying the back crank shaft bearing *D* and the crank bearings *E*. The oil splashed against the top of the fly-wheel case runs down the front sides and is led to the oil pipe *F*, which carries it to the front main bearing and flows it over the timing gears *G*. Each connecting rod *H* carries an oil dipper below it, as shown at *J*. These dippers are immersed in the oil, which is in the troughs *K*, each time the piston completes its downward stroke, and a splashing effect is produced, which serves to spread the oil in the form of a spray over the exposed parts of the motor.

The cylinder walls and piston surfaces are lubricated entirely by the spray of the oil. The wrist-pin bearings, cam shaft bearings, crank shaft bearings, and crank-pin bearings are equipped with oil pockets, which catch the condensed spray and feed it to these bearings.

In this type of lubricating system it frequently happens, that due to the desire of the operator to carry an ample supply of oil, the level in the reservoir is carried too high, resulting in the splashing of an excessive amount of oil into the cylinders, which causes carbon deposits, smoking, and waste.

The chief factors in the selection of a lubricant for automobile motors are: (1) The type of lubricating system, upon which depends the method of feeding the oil; (2) the type of cooling system, which factor has more or less effect upon the operating temperatures of the various parts of the motor.

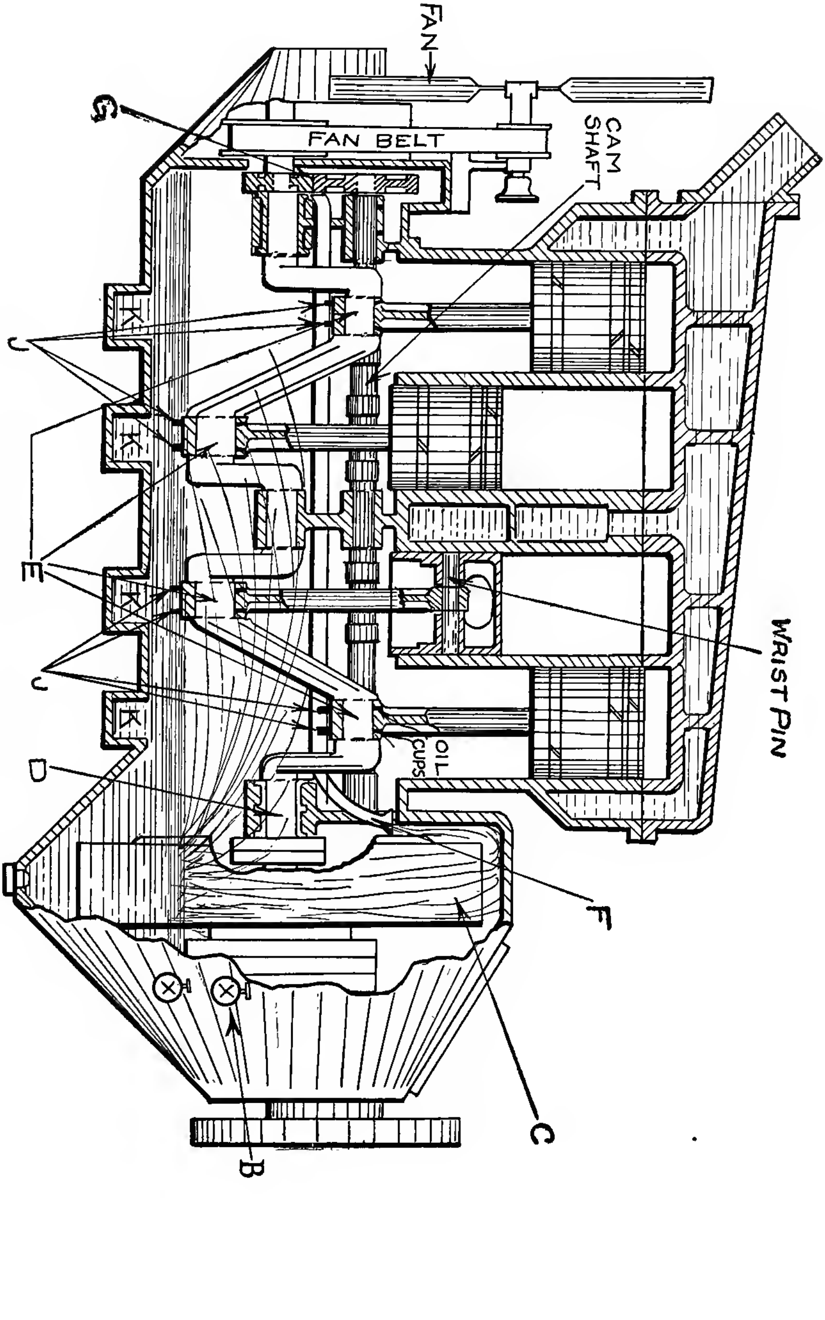


FIG. 73.—Automobile engine with splash-feed lubricating system.

In some rare cases the oil is fed with the fuel.

In those systems, which use a combination of splash and forced feed, the oil is pumped to the main bearings under pressure. Some of the oil is also pumped into a trough which runs through the crank-case, and from which the oil overflows to the connecting rod dipper troughs, from which it is splashed by the dippers to the cylinders, piston rings, crank-pin bearings, and cam shaft bearings.

Force-feed systems may be of the separate feed type, complete force-feed type, or of the partial force-feed type.

In the separate force-feed type, the oil is contained in a separate force-feed lubricator equipped with a pump, which is driven by suitable gears or chains. The oil is led, under pressure, to the main bearings and timing gears through tubes. Ducts are bored in the crank shaft, leading from the main bearings to the crank-pin and crank shaft bearings. The excess oil from the crank-pin bearings is thrown up into the cylinders. The cam shaft bearings are equipped with pockets for catching the drippings from the splash of the oil thrown up by the crank-pin bearings.

In a complete force-feed system, the oil is pumped from the crank-case pump to the cam shaft bearings, from which it is led to the main bearings. Ducts bored in the crank shaft lead the oil from the main bearings to the crank shaft bearings and from there to the wrist pins, through the ducts in the connecting rods. The cylinder walls are lubricated by the excess oil which escapes through the hollow wrist pins, and also by the oil that escapes from the crank-pin bearings and is thrown up onto the cylinder walls.

Carbon in Automobile Cylinders.—Road dust, metallic wear, or too rich a mixture of gasoline are the usual causes of the so-called " carbon deposits," which are usually unjustly blamed upon the lubricating oil. There will always be some carbon deposit formed in the cylinders of an internal-combustion engine, but it should be of such a nature that it will largely be removed with the exhaust.

An excess of oil in the crank-case will cause " carbon deposit " troubles. The level of the oil should never be carried above the height indicated by the oil gauge. Too high a level will cause the oil to work up past the piston rings into the explosion space. Here the oil is partially burnt and deposits will result.

Chemical analysis of many " carbon deposits " has indicated that about

70 per cent. of these so-called "carbon deposits" found in the cylinders of automobiles consist of mineral matter. The analyses of these deposits show a large percentage of undecomposed oil, a small percentage of decomposed oil, a little free carbon, and, as before stated, about 60-70 per cent. mineral matter.

The mineral matter is hard and abrasive and causes wear between the piston rings and the cylinders. It is introduced into the cylinders during the suction stroke of the piston, which sucks in dust from the road mixed with the air, and which eventually gets into the crank-case, where it is mixed with the oil and then is worked up into the cylinders. The heat of the explosions hardens the deposit, forming a "carbon-appearing scale." A small projection of this hard scale, remaining in the upper part of the cylinders, may become overheated and retain enough heat to ignite the incoming gas during the charging stroke. This condition is indicated by a pounding noise in the cylinder.

Missing Fire.—Missing in certain cylinders may be caused by small particles of the hard scale collecting on the spark plugs and forming a conductor for the current, thus short-circuiting the spark.

Loss in Power and Compression.—Loss in compression may be caused by small pieces of deposit working up under the exhaust valve and causing bad seating; this is indicated by a loss in power.

Removing the Deposits.—Often a small amount of kerosene poured through the priming cups, after the engine has been thoroughly heated, will loosen carbon deposit, if it is not too hard. After admitting the kerosene, allow the engine to stand over night, and on restarting, some of the deposit may be blown out with the exhaust. Oxygen is used to remove "carbon" by garages equipped with this process, and good results are obtained with it.

Notes on Filtering Gasoline Through a Strainer.—According to Mr. Ross Brooks, a fire chief of Oklahoma, gasoline should never be filtered through a funnel in which has been placed a chamois skin, as such a process while in common usage is very dangerous, due to the static electricity formed by the friction of the gasoline passing through the chamois. Mr. Brooks declares that many explosions of gasoline vapors, which have been believed to have been caused by a match, have really been caused by using chamois skin in the funnel. If the funnel is held suspended by the hand, or insulated from the tank so that no "ground" is formed, a

spark will eventually leap from the funnel to the tank and an explosion may occur, if the proper mixture of air and vapor is present.

Notes on Cylinder Lubrication.—It has been stated by some investigators that motor oils manufactured from paraffine base crudes give a more objectionable carbon deposit in the cylinder than is produced by oils made from asphaltic base crudes.

A careful practical working test to investigate this statement has indicated that the amount of carbon found in automobile engine cylinders averages the same, for high or low viscosity oils made from either paraffine or asphaltic base crudes. The consistency of all motor cylinder "carbon deposits," irrespective of the source of the oil, is about the same. The amount of carbon deposit produced depends upon the amount of oil actually reaching the upper part of the cylinder.

Transmission Gears.—The speed of an automobile is varied by alternating the engagement of different pairs of gears. These gears are operated on the leverage principle, and the driving gear really "presses" the teeth of the driven gear. Due to the enormous pressure exerted on one or two teeth at any instant, the teeth of these gears must be coated with a pressure-resisting and protecting lubricant.

Transmission gear lubricant must possess sufficient body to cushion the teeth and thus to relieve the impact of the meshed gears. The lubricant must be adhesive, so that it will cling to the teeth and resist the wiping effect produced by their sliding contact. It should not be excessively affected by temperature changes. Needless to add, it should be strictly neutral and free from gumming characteristics. When the gear case is tight and the parts in good condition, a heavy, semi-fluid grease is recommended. A cylinder stock of 160 to 175 Vis. at 212° Fahr. will give good results, if an oil is desired.

Universal Joints.—The lubrication of the universal joint, which is practically an elbow by which a shaft may turn a corner and yet revolve on its own centre, requires special attention. The lubricant is here submitted to a severe rubbing and grinding. Either a fibre grease or a hard cup grease is recommended.

The Differential.—The differential requires a slightly heavier lubricant than the transmission. A medium-bodied, semi-fluid grease will give good results.

Wheels.—A semi-fluid oil or a medium grade of fibre grease is recommended for the wheel bearings.

Steering Gear.—For the sector and worm in the steering gear housing, use a fibre grease or a heavy gear compound.

Water Pump.—Grease cups for feeding the water pump bearings and glands work best with graphited grease.

Suspension Springs.—Paint the contact surfaces of the blades with a heavy graphited grease.

Notes on Automobile Lubrication.—When considering the lubrication of automobile motor bearings, the heat conducted from the piston through the wrist-pin and connecting rods to the crank-pin bearings, crank shafts, and main bearings must be allowed for. Usually the wrist-pin bearings will run at about 300° Fahr., and the temperatures will range down to about 150° Fahr. at the main bearings.

Summer and winter temperatures usually produce approximately a 50° Fahr. range in the temperatures of the oil leaving the bearings.

Automobile oils should flow freely at a temperature of not more than 5° Fahr. for general, all-the-year use.

For leaky gear cases use a gear compound. (See Lubricants.) Ordinary cup greases, when used in gear cases, often cause " foaming " and may result in separation of the soap from the oil. If too stiff a lubricant is used, the gears will cut " tracks " through the body of the lubricant and poor lubrication will ensue. Gear compounds containing wood fibre, asbestos, or other solid matter, which is put in the compound to lessen the running noise of badly cut and worn gears, should never be used, as these substances are not lubricants, and undue heating will follow.

CHAPTER XVII

COAL MINING MACHINERY LUBRICATION

The strongly corrosive waters to be pumped in coal mining operations have a particularly bad effect upon the plungers and piston valves of the pumps. These conditions must be reduced as much as possible by suitable lubrication, so that exposed surfaces will be covered by a film of lubricant.

Mining operations are examples of methods of lubrication producing great wastes of lubricants. This is due largely to the fact, that the oiling operations are usually left in the hands of unskilled laborers, who waste more of the mine car oil than is actually used for lubrication.

The largest item of expense in the lubrication of a coal mine is that due to the large amounts of mine car oil used. The consumption of car oil at a mining operation naturally increases with the length of the " drifts " and the distances the cars must travel.

Mine cars are hauled by electric or compressed air locomotives, and an inefficiently lubricated string of mine cars will greatly detract from the hauling capacity of the locomotives.

There are numerous types of mine car wheels on the market.

Some of them are of the old style, plain-bearing type from which most of the oil was wasted by dripping off, while others are of the more improved self-oiling type, which to a more or less extent gives satisfactory results. Many mines have equipped their cars with roller bearings, which have met with some success. Many of the so-called self-oiling wheels are faulty, in that they do not provide sufficient means to prevent the oil from creeping out along the back of the hub and being lost.

Car Lubrication.—For the old style plain car wheel, a cheap grade of black oil is used, because the oil is mostly lost by dripping and only a very small amount actually furnishes lubrication. The oil should have a cold test of about 5° for winter use.

For wheels having self-oiling bearings, a free flowing good quality oil having a low cold test is recommended.

For wheels equipped with roller bearings, a semi-fluid grease should be used.

A typical mine car oil would have the following general specifications: Black oil:—

Viscosity, Summer, 90–100 (Saybolt) at 212° Fahr. Cold Test 25–30° Fahr.
Viscosity, Winter, 370–385 at 130° Fahr. Cold Test 5–15° Fahr.

Notes.—In a well-run hard coal mine, the following approximate amounts of oil were used to lubricate the pumps, cars, etc., for a period of one year, and the results are tabulated as an indication of the relative cost of lubrication of coal mines:—

Cylinder oil	8,700 gallons
Engine oil	11,400 gallons
Car oil	31,650 gallons
Cup grease	35,000 pounds
Plunger pole grease	21,600 pounds
Other oil, such as ice machine, gas engine and compressor	1,200 gallons

Total coal tonnage mined during the above period, 3,900,000 tons.

How to Oil Mine Cars.—One-quarter to one-half of the power generated at collieries, when they are operated, is used for hauling the cars.

Passenger and railway gondola cars give, on the average, from 1000 to 3000 miles per oiling. Mine cars are considered by the operators to be giving good results if they average 50 miles per oiling.

Fifty per cent. more oil is wasted than is used. Dirt, grit, and coal dust will cut the bearings, therefore all oiling holes should be kept covered.

There are several kinds of packing for use in mine car lubrication, as follows: Discarded Manila roping, Mexican sea-grass, sponges, cotton waste, and woollen waste.

Woollen waste is the best, because it is of a springy nature and therefore has a tendency to press up against the journal surfaces and bring the oil into contact with those surfaces. It will absorb the oil and gradually feed it to the journal, like a wick in a lamp.

Cotton waste becomes soggy and sags down in the "cellars." This waste also tends to fall away from the journal surfaces and glaze at the contact surface, so that it is impossible for the journal to receive oil in sufficient quantities.

Mexican sea-grass and old Manila roping do not absorb oil, but merely tend to hold it in the boxes. The grass is soon broken into small pieces and works up into the bearing, causing overheating.

The proper method for preparing wool waste for use in mine cars may be briefly described as follows:—

(*a*) Tear the waste apart, into small pieces, about the size of an egg.

(*b*) Drop these pieces into a tank containing the car oil, which is kept at a temperature of about 80° Fahr.

(*c*) Drain the wool on a screen for six hours, after it has soaked in the oil for 24 hours. While the waste is draining, it should be occasionally stirred with a pole or hoe.

Sponges will not feed every drop of oil to the journal, as wool waste will, due to many small holes in a sponge, which tend to hold the oil back.

It is a very good plan for the "oiler" to mark the date of each oiling on the journal boxes of the cars, so that a record may be kept of his work.

COLLIERY LUBRICATION

The principal machinery in a mine colliery which must receive lubrication may be outlined as follows:—

(COLLIERY)

(*a*) Steam cylinders.
(*b*) Pneumatic tools.
(*c*) Electric generators and motors.
(*d*) Air-compressor cylinders.
(*e*) Wire ropes and cables, etc.

(MINE)

(*a*) Mine cars.
(*b*) Mine pumps.
(*c*) Air cylinders.
(*d*) Wire cables and mine hoists, etc.

Notes on Coal Mining.—Every time a ton of anthracite coal and rock is hoisted from a mine, an average of eleven tons of water must be pumped from the mine.

Approximately 4000 tons per day is the output of the largest producer of anthracite in the world.

It takes about the same amount of power to pump fresh air into a mine as it does to hoist the coal out of it.

About the deepest coal mine is in the Wyoming region. It is about 2000 feet deep.

A "pick mine" is one in which the miners use hand work, picks being used to "undercut" and get out the coal. Mules are used to haul the cars. Little cylinder, engine, or compressor oil is required for this type of mine.

In some mines with long drifts, the car hauls may be as much as fifteen miles per round trip.

When figuring a lubricating tonnage contract for a "wet mine," make allowance for the continual operation of the pumps, which are kept going night and day and use large amounts of lubricants. Also, in "wet mines," water collects in the low places and washes the journal oil from the "pit car" journals, greatly increasing the amounts of car oil used, due to the frequent re-oiling.

CHAPTER XVIII

DIESEL ENGINES

DIESEL engines are used for stationary power purposes, marine propulsion, and to a limited state have been built for driving railway locomotives.

They are built to operate on the two- or four-cycle principle. The principle of combustion in the Diesel engine embraces certain fundamental conditions not found in other internal-combustion engines.

A comparison of the operating conditions in a four-cycle explosive type of engine and a four-cycle Diesel engine will best illustrate the Diesel principle. In the explosive type of engine the moving piston imprisons a quantity of hydrocarbon vapor mixed with air between itself and the head of the cylinder and compresses it. When this compressed charge is ignited by means of a hot bulb, electric spark, or by some other means, a flame passes almost instantaneously through the entire mass of gas and air mixture, producing a highly expansive and explosive result.

Four-cycle Type of Diesel Engines.—The Diesel engine does not contain an explosive mixture at any time, and no explosion occurs, therefore. No carburetor or vaporizer is required.

The four strokes required to complete the cycle of events in a Diesel engine of this type are shown in outline in Fig. 74. Referring to the figure, *A* is the intake stroke during which air is sucked into the cylinder, as the piston moves out. *B* is the compression stroke, during which the air in the cylinder is compressed to a high pressure, with a resulting rise in temperature to about 1000° Fahr. As shown in *C*, fuel oil is then pumped and atomized at high pressure into the hot air, through the atomizer valve, so that a gradual combustion occurs during a large percentage of the expansion stroke. This combustion does not produce an explosion, but is a gradual burning. Usually the spraying of the oil lasts for about 10 to 12 per cent. of the combustion stroke.

The Two-cycle Diesel Engines.—The two-cycle type of Diesel engine, which is largely used for marine purposes, has the following cycle of events: (*a*) On the upstroke of the piston, air is compressed to about 500 pounds in the working cylinder and therefore is highly heated. (*b*) Just

before the end of the upstroke, an atomizer valve is opened and the fuel oil injected. Combustion immediately occurs and continues during part of the downstroke. During the first part of the stroke, combustion occurs under constant pressure, while later in the stroke the work is done by expansion. (*c*) At the end of the stroke the gases are exhausted, through suitable ports now uncovered by the piston, and a blast of air is blown through the cylinder to scavenge it. The piston now starts to return

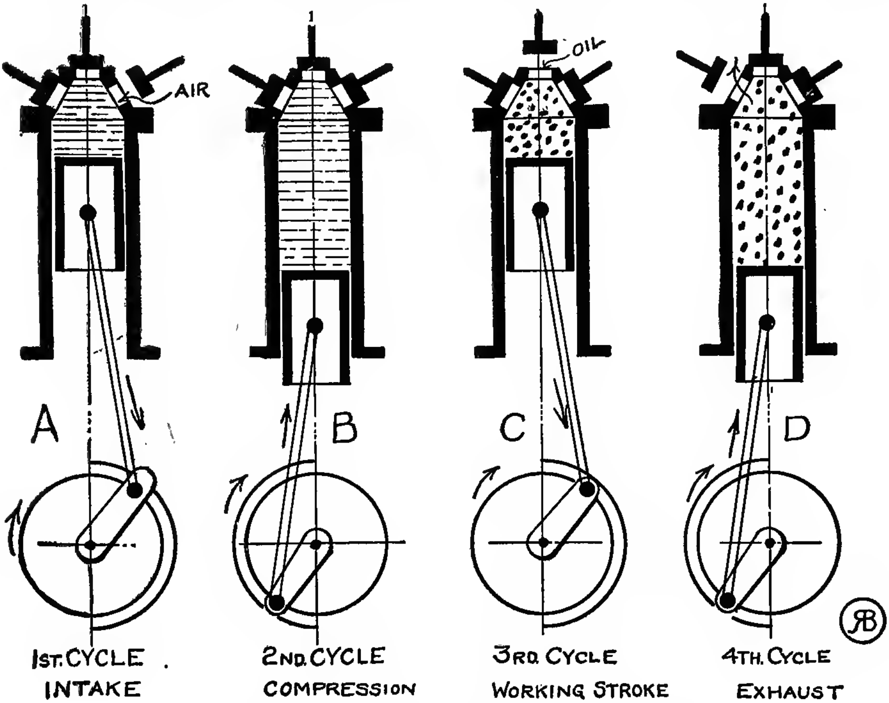


FIG. 74.—Cycle of operations in a Four-Cycle Diesel engine.

upwards, the cylinder is filled with air, from the excess of scavenging air, and the operations described before are repeated.

The cylinders and cylinder heads of Diesel engines are fitted with water-cooling spaces, to prevent excessive heating. A typical high-speed, light-weight Diesel engine of the two-cycle type (marine) would have the following specifications:—

Six cylinders, 600 normal brake H. P., 425 R. P. M.
Six cylinders, 1200 normal brake H. P., 370 R. P. M.

A typical heavy-weight, moderate speed, two-cycle engine would have the following specifications:—

Six cylinders, 600 normal brake H. P., 275 R. P. M.
Six cylinders, 1200 normal brake H. P., 210 R. P. M.

Lubricating the Diesel Engine.—Marine Diesel engines are usually lubricated by a forced-feed system. The lubricating system serves the cylinders, wrist-pins, crank bearings, and main bearings. Usually two grades of oil are used, one for the cylinders and one for the bearings, although on marine engines one oil is sometimes used for both.

In some types of marine Diesel engines, the main bearings are lubricated by wick feeds. For engines equipped with a circulating system, a strictly neutral, non-emulsifying oil should be used. For high-speed Diesel marine engines, having a circulating system, a neutral filtered oil of (150 Vis. at 100° Fahr. P. B.) (200 Vis. at 100° Fahr. A. B.) will fill the requirements.

For the heavier stationary engines, a filtered cylinder stock of about 150° Vis. at 212° Fahr. will give satisfactory results in the cylinders; this oil must be a pure mineral oil.

For heavy, slow speed, Diesel engines, that are equipped with forced-feed lubricating systems, a non-emulsifying oil of (450 Vis. at 100° Fahr. P. B.), or, (750 Vis. at 100° Fahr. A. B.) is recommended.

There are sight feeds, valves and glasses, in the various forced-feed branches, in engines equipped with this system, by which the rate of feed may be regulated.

The atomizer valves are actuated by cams, push rods, lifter rods, and valve levers. The cams are usually encased in iron boxes, which should be kept filled with a good quality cup grease, No. 2 or No. 3 consistency.

The cam shafts in four-, six-, or eight-cylinder engines are necessarily long and are supported by bearings between each cylinder. These bearings are equipped with grease cups, and No. 3 consistency cup grease will give the best results.

The gears for driving the cam shaft are encased and run in a bath of oil.

The piston speeds in the two-cycle type are usually about 700 feet per minute.

The compressor for supplying the air for starting the Diesel engine

and for injecting the fuel should be lubricated with a light-bodied compressor oil.

Starting.—The Diesel engine is started, by admitting air to the cylinders and thus operating it as an air motor, until enough momentum has been obtained to carry the pistons up against the air compression. The air starting valves are then shut and oil is admitted to those cylinders which are ready to receive it.

The function of the fuel pumps is to receive the oil from the service tank and to force it into the atomizer. When the atomizer spindle is lifted, the injection air will force the fuel charge into the hot air in the cylinder. The compressor, which may be driven from the main shaft, or from an auxiliary, serves to keep the injection air bottle charged with the necessary air to blow in the fuel. The compressor also serves to charge, while running, the air-starting bottles, which are used for initially starting the engine, as above described.

The compressor is usually of the multistage type, and the lubricating conditions are described for this type of compressor under the chapter on air compressors.

Notes on Diesel Engines.—The cylinders of the average marine Diesel engine are subjected to severe expansion and contraction, due to the admission of the "starting" air to the hot cylinders when "reversing and going ahead" in manœuvring a vessel to bring her into dock. This expansion and contraction is due to the vessel having been under way for several hours or days, with her engines running in the same direction, and the cylinders and pistons have therefore been heated to a high degree. When the orders are rung down to the engine-room to "reverse or go ahead," the fuel oil must be shut off and the engine brought to rest. "Starting air" is then admitted to those cylinders in position to start the engine in the opposite direction. This air, which is at a pressure of about 800 to 1000 pounds per square inch for two-cycle engines and 300 to 800 pounds per square inch for four-cycle engines, is admitted to the cylinders through a valve in the head. Air at these pressures when expanded through a valve or orifice drops in temperature below the freezing-point, and it can be easily appreciated that the contracting and expansive strains produced in the cylinders and pistons due to these conditions are excessive. As soon as the starting air is shut off, the compression of the air contents of the cylinders again brings the temperature up to about 1000° Fahr.

For these reasons the oil used to lubricate these engines is subjected to a very severe test, much more severe than is met with in an internal-combustion engine of the explosive type. The oil should have a reasonably low cold test, not over 10° Fahr. pour.

In certain engines special arrangements, such as step pistons, are used for air starting, in which cases the starting air is never admitted to the working cylinders, but acts upon the step pistons, which in turn become scavenging pumps for the adjacent cylinders, when the engine is running on fuel.

In some types of Diesel engines, a double-compartment forced-feed pump is provided; one compartment of the pump is supplied with cylinder oil and lubricates the cylinders, and the other compartment is provided with several pipes, which lead to the various engine and compressor bearings, as described. The oil is collected when it comes from the bearings, and after filtering is used again. Oil for use in the cylinders of these engines should have the following approximate specifications: Filtered cylinder stock, pure mineral, 130–150 Vis. at 212° Fahr., not under 525° Fahr. flash.

Diesel Engine Fuel Oil.—The United States Navy specifications for Diesel engine fuel oils, for use afloat, are as follows: Flash-point not lower than 150° Fahr.—Abel or Pensky-Martin closed cup; water and sediment none or a trace; asphaltum none.

Fuel Data.—Industrial gasoline engines usually use about 0.8 pound of gasoline, or about one pint, per B. H. P. hour.

Diesel engines average about ½ pound of fuel oil per B. H. P. hour, for a 100-H. P. engine.

Triple expansion steam engines, in good shape, will average 1½ to 1¾ pounds of coal per I. H. P. hour.

CHAPTER XIX

THE LUBRICATION OF BAKING MACHINERY: DOUGH DIVIDERS

Dough Dividers.—The efficient operation of dough dividers, such as are found in many of the large baking establishments, depends very largely upon the quality of the lubricant used on them and the method of applying it to the machine. The application of the lubricant is usually accomplished by means of automatic lubricators. These lubricators must be so adjusted that there will not be any excessive supply of oil permitted at any time, as the wasted oil will find its way into the dough and cause the bread to have an oily taste.

The lubricants generally used for the lubrication of dough-dividing machines are as follows: Lard Oil, Cotton-seed Oil, Lard Compound, Petroleum Grease, and Highly Filtered Petroleum Lubricating Oil, which is known as Petrolatum Oil.

Lard Oil and Cotton-seed Oil have the objectionable features of becoming rancid and gumming the machine bearings. These oils also have an affinity for sugar and will give a bad taste to the bread.

The most approved form of lubricant for dough machines is Petrolatum Oil. This oil is a highly refined and purified petroleum product, and, due to the fact that it is nearly tasteless, it will not give an objectionable taste to the bread. This oil does not have an affinity for sugar.

A typical petrolatum oil will have the following specifications:—

(a) Flash Point .... 390°–410° Fahr.
(b) Vis. @ 100° Fahr. .... 130 –140
(c) Cold Test .... 25°– 35° Fahr.
(d) Gravity .... 31.5–33.5 B.
(e) Colorless.

CHAPTER XX

THE LUBRICATION OF ELECTRIC STREET CARS AND INTERURBAN ELECTRIC CARS

THE lubricating requirements of the principal bearings found in electric cars, separate these bearings into three classes. These classes have been named by the manufacturers of electric cars as follows: Motor Axle Bearings, Journal Bearings, and Armature Bearings.

Motor Axle Bearings.—The bearings on which the motor is supported on the axle are called Motor Axle Bearings. These bearings are fitted with caps, so arranged that the opening, in which the oil waste is packed, is on the side of the bearing. The waste has merely to rub against the axle to convey sufficient oil for lubrication. The electric current to drive the motors is brought through by way of the wheels and axles and passed through the motor axle bearings to the motor. This electric current has a tendency to heat these bearings, and this heat being in addition to the heat of friction, produced by the weight of the motor and the rotation of the axle, often causes these bearings to run hot.

Motor axle bearings wear very rapidly. Often a wide space is worn between the box and the axle and, owing to the bearing being near to the ground, considerable grit and dirt is picked up from the track and finds its way into the bearings.

There are four factors to be considered when studying the lubrication of these bearings: (1) The difficulty of getting oil to feed through waste in a horizontal direction. (2) The temperature produced in the bearing by the electric current when the motor is under full load. (3) The metal used in the bearing and the load per square inch on the axle when the car is loaded to capacity and on the heaviest grades. (4) The condition of the bearings with reference to wear.

Journal Bearings.—The bearings, which support the weight of the car on the axles, are called the Journal Bearings. These bearings are fitted with a shoe or block, which rests only upon the upper part of the axle, so that the lower part and a section of each side of the axle is exposed to oil waste, which is packed in the journal boxes.

Journal Boxes.—The boxes which enclose the journal bearings are

called Journal Boxes and are closed by a cap. This cap should fit snugly to prevent grit and dirt from entering the bearing and causing heating and hot boxes.

Packing of Journal Boxes.—At the back of the Journal Box, where the axle passes through, there is a large opening. Journal Boxes require careful packing to prevent the oil from the waste travelling back along the axle and dropping to the track. In order to prevent this loss of oil, a plaited piece of waste, as large as can be forced between the axle and box casing, should be packed against the extreme back of the box, before any oiled waste is put in. This piece of waste should be plaited before being soaked in oil. The bearings should be packed loosely, yet snugly, with a spungent waste.

The waste used should remain elastic, after it has been soaked with oil. On the sides of the bearing, the waste should be packed to just below the centre line of the journal, and at the ends, the waste should come to only about ½ inch above the bottom of the flange, on the end of the journal.

Preparing Waste. Oiling.—Packing waste should be soaked with oil and then drained, until, at a temperature of about 100° Fahr., there will be no oil droppings when the waste is suspended in the air.

Draining.—The draining of the waste after soaking is a very important factor in reducing the amount of oil used. The waste should be spread out in layers, not more than 2 inches thick, on the draining screen. Never pile the waste on the screen, as the oil draining from the upper layers will merely resoak the partially drained waste below it.

Oil.—Car oil should have enough viscosity to keep the waste well saturated without dropping, at a temperature of at least 100° Fahr. For summer use the oil must have more viscosity than is required in winter. The oil should have a flash test of about 380° to 400° Fahr. and a cold test in winter of at least 5° Fahr.

Armature Bearings.—Armature bearings are those bearings in the frame of the motor, which carry the armature. These bearings are equipped with oil pockets for oil waste and are located directly above the shaft. There is a cap which fits over these pockets to exclude dirt and grit. Armature bearings should be packed tightly at each end of the pocket and loosely in the middle.

Packing the Journal Bearings.—When a car is in constant use, the journal bearing packing should be examined every third day, and the waste

in the centre turned at each examination, to prevent the surface of the waste next to the shaft from becoming glazed and thus feeding no oil to the bearing. The waste at the end of the pockets should be rope-twisted, so that the middle waste will be kept separated and make it easier to change. This rope-twisted waste should also be changed at frequent intervals.

Electric Railway Lubricating Contracts.—Many electric railways have contracts with the oil companies to furnish lubrication for their cars at a definite rate per car-mile. The oil company furnishes all of the oil required from time to time during the year, and charges for it at a definite list price per gallon. At the end of the year, the total car-miles are multiplied by the guaranteed cost, and if the total payments made to the oil company during the year exceed this result, the difference is refunded by the oil company, while if the total paid to the oil company is below this result the oil company simply retains the full amount received during the year. This system of making lubricating contracts on a mileage basis has some advantages, but the purchasing agent and master mechanic can obtain better results by buying lubricants by the gallon and supervising their application. Usually a saving in the cost per car-mile can be shown by the gallonage method over a mileage contract, if a careful record is kept of the amounts of oil used. Purchasing agents should remember that mileage contracts are more or less of a gamble on the part of the oil company. There is always a safe margin figured in the contract cost to cover any loss to the oil company, which may be due to the personal efficiency factor of the railroad employees, with reference to the application and use of the lubricants supplied and over which the oil company has no control; as well as any special conditions which cannot be foreseen at the time the contract is made.

Any large oil consumer such as an electric railway can buy oil under a yearly contract, at very low prices per gallon, and since the railway company has first-hand control over its employees using the oil, there are great possibilities of effecting a considerable reduction in the cost of lubrication per car-mile, if careful supervision is maintained.

CHAPTER XXI

THE LUBRICATION OF PASSENGER AND FREIGHT ELEVATORS

IN considering the lubrication of the various parts of passenger and freight elevators, the proper oiling of all of the parts having moving contact must be included, regardless as to whether they are in frequent motion or only occasionally move. This is particularly true of those parts composing the governor mechanism of the safety drum under the car. Water, which may seep through a non-waterproof floor when the car is being cleaned, is apt to cause rust and corrosion of the safety drum and mechanism, unless it is kept properly oiled or covered with a rust-protecting grease.

Hydraulic Elevators.—The internal parts and wearing surfaces of hydraulic elevator systems are usually lubricated by mixing or emulsifying the lubricant with the water in the tanks, and then trusting to the passage of the water to distribute sufficient of the lubricant over the contact surfaces. There are several soluble oils and compounds on the market for this purpose. A satisfactory soluble oil would have the following approximate specifications:—

(*a*) It should mix thoroughly with water in all proportions, to form a stable emulsion.

(*b*) It should be in liquid form and composed of not less than 20 to 30 per cent. of a soluble alkali soap and the remainder of a mineral oil, compounded with a small quantity of rosin.

(*c*) The oil must be free from mineral acids and free alkali.

(*d*) The oil must show no corrosion on a polished surface that is kept in contact with it for at least two weeks.

The Plungers.—The plungers of elevators, plunger pumps, etc., require that close attention be paid to their lubrication. If allowed to become dry, they will cut and wear out the packing quickly, in addition to the increased friction, scratching and scoring of the surfaces. A good graphited grease will produce excellent results on these surfaces, as this grease will withstand the washing effect of condensed moisture, which often is present on the surfaces of the plungers. A good grease for this

purpose will have the following specifications: It should soften without flowing at 110° Fahr.; should consist of about one part amorphous graphite and two parts mineral cup grease.

Worm Gear Lubricant.—Worm and gear are important parts of electric, steam, or belt-driven elevators. An oil composed of a mineral cylinder stock mixed with castor oil will give satisfactory lubricating results.

Motor and Traction Bearing Lubricants.—For the bearings of the electric motor, which are usually equipped with ring oilers, a light, neutral oil of about 150 Vis. at 100° Fahr. is recommended. For the bearings of gearless traction machines, a slightly heavier oil is required, such as a non-emulsifying oil of [180 Vis. at 100° Fahr. (P. B.)] or [200 Vis. at 100° Fahr. (A. B.)].

Elevator Guides.—When automatic guide lubricators are provided, a high viscosity oil of about [470 to 480 Vis. at 100° Fahr. (P. B.)] will give good results. If an asphalt base oil is proposed, it must have a viscosity at the working temperatures, corresponding to the viscosities of the above-named oils at the working temperatures. Good results are obtained by using a low viscosity cylinder stock, having 110 Vis. at 212° Fahr.

Wire Cables.—The wear of wire cables is both external and internal, the former being due to abrasion and chafing against the pulleys, sheaves, etc., and the latter due to the rubbing of the wires of the strands upon one another in bending under load. The chief trouble from wire cables is caused by rust. The cable must be internally as well as externally lubricated. The lubricant should protect the outside wires from wear and rust, and should also penetrate the cable, to reduce the friction between the internal surfaces of the wires.

Many lubricants have been tried for this purpose with varying success. A petroleum pitch product, having a consistency of a very heavy cylinder oil, will stick to the cable and resist any peeling action or chafing effect, as well as lubricate the interior wires, by penetrating between the strands.

There are several oilers on the market for elevator cables. It is claimed that oil will penetrate quickly between the strands, and will not leave a sticky, dust-collecting coat on the cable. A heavy engine oil of [350 to 375 Vis. at 100° Fahr. (P. B.)], or [450 to 500 Vis. at 100° Fahr. (A. B.)], will give the best results with these oilers.

For the compression cups of sheaves, and all bearings fitted with grease cups, use a good grade of mineral cup grease of No. 3 body.

CHAPTER XXII

FLOUR MILLING MACHINERY

Mill Lubrication.—The most important points of lubrication in a flour mill are the journals of the rolls used in the grinding machines. These rolls weigh from 90 pounds, for a 6-inch x 6-inch roll, to about 2540 pounds, for an 18-inch x 30-inch roll. Roller mills are referred to as "Two Pair High," or "Three Pair High," depending upon the number of pairs of rolls in the machine.

The rolls of each pair are driven at different relative speeds, and thus each pair of rolls has one roll driven from the "fast side" and one roll driven from the "slow side." The rolls may be driven by belts, on both the slow side and the fast side, or belt drive may be used for the fast side and gear drive for the slow, or differential, side. The rolls are made with corrugated or with smooth surfaces, depending upon the class of work they are designed to do.

Roll Data.—The rolls of typical roller mills will have the following approximate diameters and speeds:—

Two Pair High Roller Mills (Ring Oil Bearings)

Size of Rolls	Horse-power	Speed of top Fast Roll	Diameter of Journal
6″ x 12″	3 to 5	600	2⅛″
9″ x 14″	5 to 8	500	2¼″
9″ x 30″	12 to 18	500	2⅝″
10″ x 36″	20 to 25	450	3⅜″

Two Pair High Ball Bearing Roller Mills *

Size of Rolls	Horse-power	Speed of top Fast Roll	Diameter of Journal
6″ x 12″	2 to 3	600	2 1/16″
9″ x 30″	7 to 11	500	2⅝″

Conveyors.—Flat belt and cast-iron spiral conveyors are widely used in flour mills. "Carriers," for grain conveying belts, are spaced about 5 or 6 feet apart, and for "return rollers," at about 8 to 10 feet apart. These carriers should receive periodic attention and their oil cups be kept filled with a good red engine oil, having a viscosity of about [275° at

* NOTE.—For the three high roller mills, the roll dimensions and speeds are about the same; the capacities and required driving horse-power are, of course, higher.

The rolls are run under a pressure of about 2000 pounds to 5000 pounds per journal.

100° Fahr. (P. B.)] or [350° at 100° Fahr. (A. B.)]. The speed at which the belt conveyors run is, on the average, about 750 feet per minute.

Standard spiral steel conveyors will have the following general specifications:—

Outside diameter of Conveyor	Lengths between bearings (centre)	Average speed per minute
6″	10′–0″	200
9″	10′–0″	170
14″	12′–0″	140
18″	12′–0″	120

Packers.—Barrel and sack packers usually contain a pair of bevel gears. These machines are run at about 200 R. P. M. and are lubricated by hand oiling.

Exhaust Fans.—These fans are designed for taking the hot air from the rolls and for other purposes. The speeds of the machines will usually range from 500 to 800 R. P. M. for wooden fans and from 300 to 550 R. P. M. for cast-iron exhaust fans, depending upon the size of the fan and the pressure desired. Oil cups are provided on the bearings.

Dust Collectors.—There is considerable dust in the air in flour mills. Exhaust fans and cyclone collectors are used to free the air of dust, and these machines, which are run at high speeds, should be freely lubricated with a medium-bodied red oil of about [175 Vis. at 100° Fahr. (P. B.)] or [205° to 210° Vis. at 100° Fahr. (A. B.)].

Notes.—The dust in flour mills is excessive and the bearings are rarely free of a coating of it. The bearings are mostly hand fed, and for this reason are frequently neglected for too long a period of time. Large savings in power can be effected in the average flour mill by scientific lubrication.

For the quick-running gears of the roller mills, a medium-bodied gear grease (see index) should be used, or a light-bodied pinion grease will give satisfactory results, provided its consistency is very low.

Many flour mills are equipped with rope drives. The ropes should be lubricated with a good penetrating grease, since the wear of driving rope is both external and internal. The internal wear of the rope is due to the fibres moving over each other under pressure, in bending on the sheaves, and the external wear is due to the slipping and wedging effect, occurring on the sheaves. The size of the pulleys has an important effect

upon the wear of the rope: the larger the sheaves the less the internal movement of the fibres, and the lower the internal friction.

Under normal conditions, cotton ropes do not require as much lubrication as Manila ropes, because their fibres are not as rough. Avoid placing an excess of grease upon the ropes, or the dust in the mill will soon collect upon them. Manila rope is almost universally used for transmission of power. Grease for use on Manila roping should be of fairly soft consistency and should be free of any excess of alkali or rosin.

CHAPTER XXIII

REFRIGERATING AND ICE-MAKING MACHINERY

Refrigeration.—A refrigerating machine is a heat engine reversed. There are two systems of refrigeration in general use; namely, the Absorption System and the Compression System. The system most generally met with and furnishing a field for lubrication is the Compression System.

Compression System Described.—In the Compression System, anhydrous ammonia gas is compressed in a compressor, to a high pressure, about 130 to 200 pounds per square inch. During the compression, the temperature of the gas becomes quite high, about 200° Fahr. This hot gas is cooled by passing it through a condenser containing cooling water, and is relieved of most of its "heat of compression." The gas is then run into expansion coils, which are surrounded by brine. Here the gas is expanded from its high pressure down to about 10 pounds, and in so doing, it reverses the compression conditions and absorbs heat to make up for the heat given up to the condenser, causing the brine surrounding the coils to become cold and producing a refrigerating effect. The brine is run out to the freezing-room in pipes, which surround the "freezing cans" in which the ice is made. In the "can system" 300 pounds of ice, approximately, is made in each can and the freezing requires 40 to 48 hours.

Lubricating Conditions.—There are certain conditions existing in this class of machinery which require especially careful attention, in choosing and applying lubricating oils.

Ammonia Cylinders and Ice-machine Oils.—For the lubrication of the ammonia compressor cylinders, a pure mineral oil of good flash test (365° to 400° Fahr.) and possessing a cold test of 0° to 5° Fahr. should be used. The heat of compression of the ammonia gas requires that the oil have a good flash test, since it must not vaporize too quickly. The possibility of oil leaking, or being carried in vapor form, with the ammonia gases into the condenser pipes and expansion coils, requires that the oil have a good cold test, to prevent its solidifying in the piping. A fairly low viscosity oil should be used, one having about 100 viscosity at

100° Fahr. for a P. B. oil and 110° viscosity at 100° Fahr. for an A. B. oil, being the best.

Stuffing Boxes.—Hot ammonia gas has a very bad effect on the stuffing box packing of ammonia compression cylinders. A liberal supply of lubricating oil should be applied at this point, to reduce the possibility of overheating the stuffing box.

Lost Capacity.—One reason for lost capacity in refrigerating plants is due to the carrying over of the lubricating oil by the ammonia gases and the depositing of this oil on the interior of the condenser and expansion coils. This trouble is due largely to the common mistake of locating the oil separator entirely too close to the discharge of the compressor. The gases at this point are very hot and the oil is mostly in vapor form. If the separator is located near the condenser, where the gases have slightly cooled and some of the oil condensed, it is much easier to prevent an excess of oil being carried into the condenser coils.

Oil Traps.—Oil traps, which may be made of a short piece of 3- or 4-inch piping, about 2 feet long, should be located at the lowest places in the expansion and condenser coils.

Measuring Oil Fed.—All oil used to lubricate the ammonia compressor cylinders should be measured and a record kept. If there is any unusual increase in the amount of oil fed into the cylinders, immediate investigation should be made, to prevent "filling" of the system.

Oil in Condenser Coils.—If lubricating oil has gotten into the condenser coils, it can be loosened by cutting off the water from one stand at a time, and allowing the coil to become hot, when the oil will be thinned and can be run off at the oil trap.

STEAM CYLINDERS OF AMMONIA COMPRESSORS

Exhaust Steam Used to Make Ice.—The exhaust steam from the steam cylinders of ammonia compressors is usually condensed, purified, and utilized to fill the freezing cans.

The exhaust steam first passes through a separator to take out the free cylinder oil, then through a feed-water heater to return some of the heat in the steam to the boiler, by way of the feed-water. The steam is next condensed, re-treated, and the condensed water is skimmed to catch any oil still in it. The condensed water is further filtered, settled, and finally filtered again and piped to the "freezing cans."

Steam Cylinder Oils.—Cylinder oils used in the steam cylinders of refrigerating machinery should be pure mineral, uncompounded oils. A mineral cylinder oil is more easily separated from the exhaust steam than a compounded oil. Either a filtered or unfiltered cylinder oil may be used. Absence of compound is the most important requirement to prevent the formation of an emulsion, with the consequent difficulty of removing this emulsion from the exhaust and condensed steam.

Special Conditions.—In some plants, steam conditions force the use of a compounded cylinder oil, and for these cases it is best to use a filtered oil.

Other Tests.—The cold test, flash test, and viscosities of cylinder oils for use in ice-making plants should be the same as those recommended for steam-engine cylinders under the same steam conditions.

Piston Speed.—The piston speeds of the steam end of ammonia compression machinery are usually not more than 400 feet per minute, and the cylinders should, therefore, require a minimum amount of cylinder oil. The smaller the amount of oil used, the easier to prevent trouble from discolored ice.

Discolored Ice.—The most frequent complaint from operators of refrigerating machinery is caused by the discoloration of the ice.

Cause.—If the cylinder oil is not entirely removed from the exhaust steam, it will eventually pass into the freezing cans with the condensed water. Oil discoloration usually shows in the form of a " fan " in the block of ice. The " fan " shape of the discoloration is caused by the oil floating on the top of the water in the can, as the ice freezes from the bottom up.

Rusted Cans.—Many complaints against discoloration of the ice that are blamed on the lubricating oil, can be traced to the fact that when the plant was shut down, some condensed water was left in the freezing cans. Condensed water causes rust to form very quickly, and this rust will cause discoloration of the ice. This condition occurs very often and should always be investigated at once by the oil man adjusting the complaint.

CHAPTER XXIV

INTERNAL-COMBUSTION ENGINES (EXPLOSIVE TYPE)

THE greater part of the internal-combustion engines of the explosive type in active use are operated on the four-cycle principle.

Each of four strokes required to complete the cycle of events in a four-cycle engine of the horizontal type is shown in detail in Fig. 75.

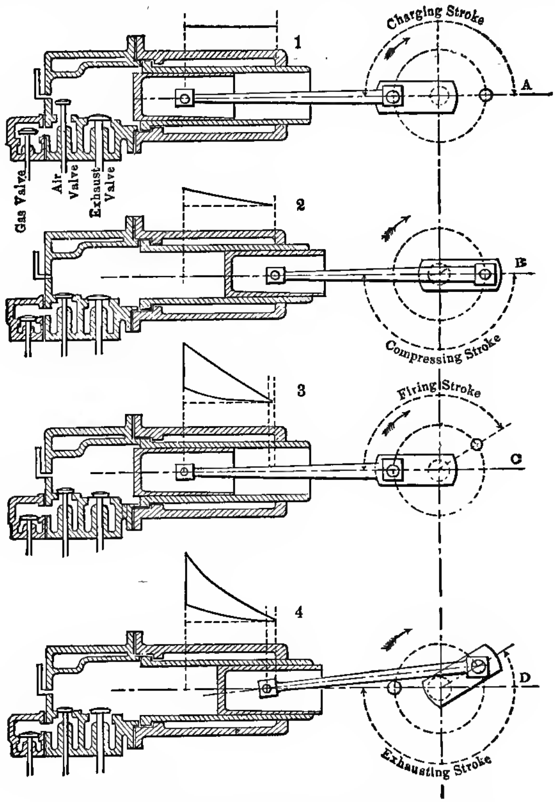


FIG. 75.—Four-cycle internal-combustion motor.

There is a power, or impulse, stroke every other revolution of the crank, or every fourth stroke of the piston.

Referring to Fig. 75, in the first outward stroke (A), the mixed charge of gas and air is drawn into the cylinder. This is called the "charging stroke." On the return stroke (B), the air and gas valves are closed and

the contents of the cylinder are compressed. This is called the "compression stroke." At or near the end of the "compression stroke," the compressed gas is ignited by means of an electric spark, hot tube, hot bulb, or some other means of ignition. Expansion due to the temperature rise and resulting volumetric increase takes place in the charge, as the piston is moving outwards. (*C*) is called the firing stroke. On the return of the piston, the fly-wheel, which has been given enough momentum, carries the piston back. The exhaust valves have been opened and the burnt gases are displaced. This stroke (*D*) is called the exhaust stroke.

Compression.—In the usual internal-combustion engine, using gasoline or similar fuels, the compression is carried up to about 90 pounds per square inch.

Piston Speeds.—Usually piston speeds are between 500 and 700 feet per minute, but in some cases may be outside of these limits.

Indicator Diagram.—The corresponding parts of the indicator diagram are shown above each of the strokes in Fig. 75.

Two-cycle Engines.—In the two-cycle, internal-combustion engine there is a power stroke for every revolution of the crank, or for every outward stroke of the piston. The cycle of events in this type of engine is completed for every revolution of the crank. The piston speeds are usually lower in two-cycle engines than those in four-cycle engines.

Lubricating Conditions.—The lubricating conditions are more severe in a two-cycle engine than in a four-cycle engine, because the lubricating film on the walls of the cylinder is exposed to the explosion heats for each revolution of the crank, instead of every other revolution, as with the four-cycle engine. The two-cycle engine is not in general use to-day for various mechanical reasons.

Fuels.—Various fuels are used in internal-combustion engines of the explosive type; such as gasoline, kerosene, producer gas, illuminating gas, etc.

Coke-oven and Blast-furnace Gases.—The waste gases from coke ovens are cleaned and used for power purposes. These gases are rich in hydrocarbons. Blast-furnace gases are cooled and cleansed and used in the engines of the adjoining plants.

Producer Gas.—The most important of the so-called fuel gases is Producer Gas. The apparatus used for generating this gas is called a "producer," and it is usually supplied with a small-sized anthracite coal, as fuel.

Producers.—There are in common use two types of producers. In one type, air or steam (or both together) is forced under pressure from a blower, up through a bed of solid fuel in the producer. In the other type, the suction of the charging stroke of the engine itself, draws the air and steam through the bed of fuel. This last type is called a "suction producer."

Illuminating and Natural Gas.—Illuminating gas from the city mains and in certain restricted areas where available, natural gas, is used as fuel for internal-combustion engines.

Calorific Values.—Some approximate idea of the calorific (heat) values of the various gas-engine fuel gases may be obtained from the following table:—

Gas	B.T.U. per cubic foot	Gas	B.T.U. per cubic foot
Natural	886–1000	Coal	695
Water	295	Producer	135

Characteristics of Fuel Gases.—The characteristics of the various gas-engine fuel gases, which may have an influence upon the lubrication of the cylinder of the engine, using any one of them, are thus outlined:

Natural Gas.—Rich, pure, and slow burning.

Coal Gas.—Made by the destructive distillation of coal, in closed retorts. Not commonly used because of the high cost.

Producer Gas.—Usually contains some water, slow burning and lean.

Coke-oven Gas.—Good gas, but high in sulphur and hydrogen. Should be carefully cleaned and drawn off early in the oven run.

Blast-furnace Gas.—Good gas for high compression engines. Very lean and sluggish and usually contains dust.

Lubrication of Industrial Engines.—The following recommendations may be used as a guide in the selection of the proper lubricant, for gas engines using the following named fuel gases:—

Natural Gas	Free flowing mineral oil of about 170 to 180 Vis. at 100° Fahr. (P. B.). 220 to 250 Vis. at 100° Fahr. (A. B.).	
Blast-furnace Gas: Producer Gas: Coke-oven Gas:	Oil having Vis. 300 to 310 at 100° Fahr. (P. B.). Oil having Vis. 500 to 550 at 100° Fahr. (A. B.). Owing to sulphur and other impurities, occurring in blast furnace and the other gases, especial care must be given to the lubrication of these engines. Forced-feed lubricators are usually used for the cylinders. The stuffing boxes are water cooled.	
Other fuels: Gasoline Kerosene Illuminating Gas	Red or pale oil of 225 to 250 Vis. at 100° Fahr. (P. B.). 350 to 375 Vis. at 100° Fahr. (A. B.).	Industrial, Stationary Engines

Any of the petroleum gas-engine oils on the market will have a sufficiently high flash-point. Generally this is about 400° to 410° Fahr.

Types of Engines.—The two main types of internal-combustion engines of the explosive class are the Vertical, having vertical cylinders, and the Horizontal, having a horizontal cylinder, or cylinders, as in a tandem gas engine.

Engines used for industrial purposes are usually of the horizontal, four-cycle type, with a single cylinder, or with tandem cylinders. The lubrication of the cylinders of the horizontal internal-combustion engine may be by direct feed, or by splash feed. In some engines, telescopic oilers are arranged to feed through the wrist-pin to the cylinder walls. Particular attention must be paid to the lubrication of horizontal gas engines, because the weight of the piston is carried upon the lower cylinder walls.

Vertical Engines.—There are several methods used for the lubrication of vertical combustion engines, namely: The Splash System, the Forced-feed System, and a combination of the Forced and Splash-feed Systems. Vertical gas engines have one, two, or more cylinders. Each cylinder has its own crank on the main crank-shaft of the engine. The operations of the above-named lubricating systems are as follows:—

SPLASH SYSTEM

In the Splash System, the crank-case is of the enclosed type and acts as an oil reservoir. Each cylinder is lubricated by the splash of its crank, as it revolves and is immersed for a fraction of an inch below the surface of the oil. On its upward stroke, the oil which adheres to the end of the rod, or to the small dipper on the end of the rod, is thrown violently against the exposed parts of the cylinder walls. The piston is then depended upon to carry the oil up and spread it over the upper walls. Each upstroke of the piston brings fresh oil from the crank-case to the cylinder walls. The wrist-pin, crank-pin, and main bearings are lubricated by the splashed oil, which is caught in small pockets and led to the bearings, or, as in the case of many engines, a fin on the sides of the crank-case collects the oil draining back to the reservoir and leads it to the main bearings.

The following points are important with reference to the efficiency of this type of feed:—

(*a*) The oil in the reservoir soon becomes dirty and unfit for lubri-

cation, although it is repeatedly thrown onto the surfaces to be lubricated, when it is in this condition, and is expected to do good work.

(*b*) The distribution of the lubricant is not positive, but depends upon several varying conditions.

(*c*) The level of the oil in the crank-case must be maintained within fairly uniform limits. Too high a level causes an excess of oil to be thrown violently against the lower part of the piston, with the result that some of the oil is carried past and above the piston rings, causing excessive smoking and cylinder deposits. (See "Carbon Deposits" in index.)

(*d*) The viscosity of the oil used has an immediate effect upon the amount of oil splashed, and hence upon the oil available for lubrication. The heavier the oil, the smaller the amount splashed.

Forced Feed.—Many vertical and some horizontal internal-combustion engines are lubricated by the forced, or positive feed system. In the forced-feed system, the oil from the reservoir or sump, which is located at the lowest part of the crank-case, is pumped through a fine-mesh strainer and through suitable distributing feed channels, to the various points requiring lubrication.

The oil may be carried through hollow crank, cam, and other shafts to the various bearings, or through separate direct oil feeds which lead from a central manifold, equipped with individual sight feeds and control valves which regulate the amount of oil fed.

Discussion of the Lubricating Conditions in the Cylinders of Four-cycle Internal-combustion Engines.—In the usual internal-combustion engine cylinder, operating upon the four-cycle principle, the charging, compression, and firing strokes do not present any particularly difficult problem from the standpoint of successful lubrication. During the exhaust stroke, however, when the piston is returning and expelling the hot exhaust gases from the cylinder, it is evident that the lubricating film remaining upon the cylinder walls, after having been subjected to the high temperatures of the preceding firing stroke, must furnish the only form of lubrication, with the exception of that oil which is being brought up by the piston itself, on this return stroke. A study of the conditions affecting the lubricating film during the firing stroke and the probable condition of this film, with reference to its ability to furnish lubrication for the exhaust stroke, is therefore of the greatest importance.

In the past it was believed that lubricating oil for use in the cylinders

of internal-combustion engines should possess a high flashing-point, to prevent its destruction during the firing stroke. This theory has been given up for the following reason: In order to obtain a flashing-point of over 500° Fahr., with a petroleum oil, it is necessary to use a cylinder stock oil, with all of the resulting disadvantages of slow distribution of the lubricant, due to its high viscosity at normal and even fairly high temperatures. The average working temperatures in the cylinders of internal-combustion engines are far above 500° or even 600° Fahr., so that even a high test oil will be burnt with practically as much rapidity as an oil having only 400° Fahr. flash test and a much lower viscosity. It has been demonstrated by many practical tests, that the most important characteristic of an oil, in the lubrication of internal-combustion engine cylinders, is its viscosity. The viscosity should be as low as practicable, to permit of a quick and efficient "spread" of the oil over the cylinder walls. The flashing-point of the oil is of minor importance.

Due to the fact, that the same oil is used for both the cylinders and the bearings of internal-combustion engines of the light high-speed type, now in most general use in automobiles, motor-boats, etc., it is desirable, and the best lubricating efficiency can only be secured, by using an oil having a viscosity, at the average running temperatures of the bearings, that is just sufficient to meet the physical operating conditions of these bearings, so that the distribution of this same oil over the surfaces of the cylinder walls will be accomplished with speed and effectiveness and not retarded by an unnecessarily high viscosity. The following theoretical discussion illustrates the fact, that the outer part of the lubricating oil film, when exposed to the hot gases during the firing stroke, protects the inner part of the film, which remains upon the cylinder walls. It is important, therefore, to quickly replace this outer film with fresh oil after the firing stroke, which demands a free-flowing, low viscosity oil. The bearings are heated by conduction, through the metal of the connecting rods, etc., and the oil is compelled to work under high bearing temperatures. The viscosity of the oil should be sufficiently high to allow for a reduction, due to the bearing temperatures.

Theoretical Discussion.—Due to the high rubbing speeds of the piston, the period of time, during which the lubricating film is exposed to the high temperatures of the firing stroke, is very short. The maximum temperatures usually met with in the cylinders of internal-combustion

engines are usually about 2700° Fahr. This is the maximum temperature for the cylinder gases, and the temperature range will probably run as low as 250° Fahr., thus giving a mean temperature of the gases, for the complete cycle, of about 950° Fahr.

A film of petroleum oil, if exposed to a high temperature as described above, will not be instantly burnt, but will require that it be exposed to this high temperature for an appreciable length of time before it will be destroyed. It must, therefore be assumed, that in the cylinders of these engines the high speeds and loss of heat in its transmission to the lubricating film, will result in only a partial destruction of the lubricating film. There will be, therefore, a partially destroyed film of lubricant, remaining upon the walls of the cylinders after the firing stroke has been expended. It is the heat conditions, to which this remaining film is exposed, that determine the severest requirements made on the lubricant, because this film remains on the walls of the cylinder, which are hot, for a longer time than the outer film is exposed to the hot gases. While the cylinder walls are at a lower temperature than the hot gases, the increased time of exposure of the inner film to their heat, causes the lubricating film as a whole, to be attacked on the hot gas side by high temperatures for a short period of time, and, on the cylinder wall side, by lower temperatures for a longer period of time.

The value of the outer film as a heat-protecting blanket for the inner film may be relatively compared as follows: In a paper read before the Institute of Naval Architects in England, it was stated that "a film of lubricant one one-hundredth of an inch thick, a layer of boiler scale one-tenth of an inch thick, and a steel boiler plate 10 inches thick, offer equal resistance to the passage of heat."

In Bulletin No. 18 of the Bureau of Mines, on the subject of "The Transmission of Heat into Steam Boilers," considerable data have been obtained, bearing upon the losses in heat between the moving gases in a boiler and the boiler water. These results are of value in this investigation, because in many ways the conditions are the same.

The following data are taken from this Bulletin:—

The largest loss in the transmission of heat from the hot gases to the boiler water occurs in its transmission from the hot gases to the dry surface of the boiler tubes. The boiler tubes are, of course, covered with a layer of soot, then comes the metal, then the boiler scale, and last

the water. The estimated, or figured, losses, as outlined in the above-mentioned Bulletin, are as follows:—

Initial temperature of the gases, 2500° Fahr.

The temperature of the gases escaping to the stack is 600° Fahr. Then the average temperature of the moving gases would be $\frac{2500+600}{2}$ = 1550° Fahr.

There were found to be the following temperature drops:—

	Degrees Fahr.	Per cent.
From the hot gases (moving) to the soot surface ..	1047	67.6
Through the soot layer	65	4.18
Through the boiler tube	13	.84
Through the boiler scale	65	4.19
From the scale to the water	10	.64
The resulting temperature of the boiler water	350	22.55
	1550	100.00

The clearance, between the piston and the walls of an internal-combustion engine cylinder, varies from about 0.001 to 0.01 of an inch. The piston rings are fitted so closely that there is only a very thin film of oil permissible between them and the cylinder walls, and, at the temperatures reached here, all oils, whether originally light or heavy, will have about the same film thickness. It may therefore be assumed, that the heat-resisting value of the oil film in the engine cylinders and that of the soot covering in the above-described boiler will be about the same, for all motor cylinder oils. Knowing the average temperatures of the gases in the cylinders, it is possible to estimate the temperatures to which the inner lubricating film is exposed, as previously explained, by assuming the same ratio of heat losses as those outlined in the results of the boiler investigation.

Referring to Fig. 76, which illustrates the path of the heat transfer, from the gases to the cooling water of an engine cylinder:—

	Per cent.	Degrees Fahr.
In passing from G to F^2	67.6	642
In passing through F^2	4.18	39.83
In passing through F^1	4.18	39.83
In passing through C	.84	7.97
In passing from C to W	.64	6.47
Transmitted to the water	22.55	213.90
		950.00

The cooling water is boiling, indicating severe conditions.

It is shown by the above table that with worst working conditions, but with efficient renewal of the outer protecting film:

The gas side of the "*inner lubricating film*" is exposed to only:

$950° - 642° - 39.83° = 268.17°$ Fahr., which is well within the flashing-point of any oil.

The "*cylinder wall side*" of the inner film is exposed to:

$950 - 642 - 39.83 - 39.83 = 228.34°$ Fahr., so that the continued exposure of the inner oil film to this surface will not destroy it, *Provided the viscosity of the oil, at normal temperatures is low enough to permit the outer protecting film of oil to be renewed efficiently, after each explosion stroke.*

Summing up the results: It is evident from the above, that oils which are abnormally high in viscosity at normal temperatures will not give satisfactory lubrication in the cylinders of internal-combustion engines, because their viscosity cannot be reduced quickly enough, by the heat of the moving parts, to enable them to have a sufficiently low viscosity to form a quick-spreading film, which is entirely dependent upon the mechanical spreading action of the piston.

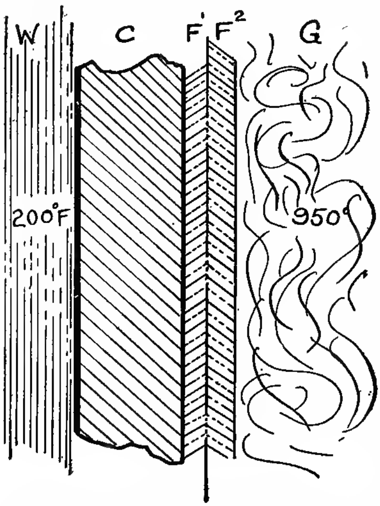


FIG. 76.—Sectional view of cylinder wall, illustrating temperature fall between the gases and the cooling water of an internal-combustion engine.

It is also evident that high viscosity oils will add an unnecessary friction load to the piston.

It is also shown that it is the heat-resisting properties of the outer film, that permit any lubrication for the exhaust stroke of the piston, in that, at the first shock of exposure to the explosion heats, this film must burn slowly enough to protect the inner film, until the hot gases have begun to move fast enough to produce the large drop in the transmission of the heat, that will then occur.

Cylinder Deposits.—All petroleum oils are hydrocarbons. Petroleum lubricating oils consist of about 85 per cent. carbon and about 15 per cent. of hydrogen. Therefore in any internal-combustion engine cylinder, when the outer film of lubricant has been partially, or entirely, destroyed

by the heats of the firing stroke, there will necessarily be some carbon liberated. This carbon, however, should be of such a nature that it will be expelled from the cylinder, along with the exhaust.

If the vaporization of the outer oil film leaves a gummy residue, the liberated carbon will stick to it and remain in the cylinder. Dust, from the air mixed with the incoming fuel, will be absorbed by this residue, and gradually a thick deposit will be built up, which soon is baked into a hard, so-called " carbon deposit."

These deposits are usually produced by the following causes:—

(*a*) Feeding an excess of oil.

(*b*) Leaky piston rings.

(*c*) Too viscous an oil used.

There is no petroleum lubricating oil that is free from carbon, although many manufacturers have made this claim through their salesmen and advertising.

Carbon Residue.—The " carbon residue " obtained in the laboratory must not be confused with the so-called " carbon deposits " found in the cylinders of internal-combustion engines.

The carbon residue in an oil may be " fixed," by distilling a known amount of the oil by destructive distillation, to dryness, in a standard flask. A coating of carbon will remain on the sides of the flask, and the percentage of this deposit may be obtained, by weighing it. This is called the " carbon residue " of the oil.

The percentage of " carbon residue " in an oil is no gauge of the amounts of " carbon, or cylinder deposits," that will be formed in engine cylinders by the oil. The percentage of " carbon residue " usually increases with the viscosity, being smallest for very light oils.

It is indicated by practical tests, that the consistency of the various deposits in combustion cylinders, produced under similar operating conditions of the engine, will be about the same for all oils, from either paraffine or asphalt base crudes.

Color of the Oil.—The color of a lubricating oil for use in the cylinders of internal-combustion engines is no indication of its deposit-forming characteristics. Red oils, if properly refined, are as efficient as pale oils for cylinder lubrication.

Cold Test.—Lubricating oils for use in combustion engine cylinders should flow at 10° Fahr. or lower.

CHAPTER XXV

MARINE ENGINES AND MARINE OILS

Notes on Marine Lubrication.—The conditions governing the lubricating requirements of marine engines are different in many respects from those governing the lubrication of stationary engines.

Reciprocating engines used in the marine trade are of the vertical type, in which type of engine the weight of the piston is not dragged on the bottom of the cylinder, as is the case in the horizontal type of engine. As a result, there is less frictional wear in the cylinders of marine engines and consequently less necessity for a cylinder lubricant.

Steamers plying in the off-shore, or salt-water trade, are provided with surface condensers, to condense the exhaust steam from the engine and thus economize the fresh water suitable for boiler use. The condensed steam is pumped by the feed pump back to the boilers, to be made into steam again. If cylinder oil is used in the cylinders of the engine, it will be carried out with the exhaust steam into the condenser, causing poor efficiency. Some of the oil will be carried by the feed-water into the boilers, causing trouble due to " bagged plates " and other causes. For this reason, and also due to the fact that little lubrication is required by the cylinders, no oil should be used in them.

For boats plying in fresh water, or in the coastwise trade, a little cylinder oil fed to the cylinders will prevent rusting troubles and reduce the friction load.

The piston rods of all types of vessels should be occasionally swabbed with a good quality of steam-refined cylinder stock oil. For this purpose, an excellent oil would have the following general specifications:—

(*a*) About 150° Vis. at 212° Fahr.
(*b*) Unfiltered.
(*c*) Flash over 500° Fahr.
(*d*) May, or, may not have 5 to 10 per cent. acidless tallow oil compound.

Water Polish.—The cylinders of marine engines, in which no oil is used, take on a so-called " water polish."

This " water polish " is a thin, hard skin, formed upon the surfaces of contact, when the condensation water furnishes the only lubrication.

It gives a very smooth, satisfactory surface, but if the ship is in port for some time, with her engines standing still, this surface is quickly lost, and unless protected by a coating of cylinder oil or vaseline, the cylinder surfaces will soon rust. It is therefore advisable to feed cylinder oil to the cylinders of a ship just before she docks.

Practically no ships in the United States Navy use cylinder oil direct to the cylinders, or valves, either in the main engines or in the auxiliaries, ventilating, or reversing engines. Swabbing oil is used, however, on the piston rods, to prevent undue wear in the stuffing-box packing.

In some marine engines, "D" slide valves of the ordinary or double-ported type are used. These valves, if heavy, are usually connected at the top to a balance piston. The "balance chamber" is practically an inverted dashpot, with the bottom exposed to the atmosphere. The "clearance" on the top of the balance piston is connected to the condenser, in which a vacuum of about 26 inches is carried. The dead weight of the valve is thus removed from the eccentrics and link block. The balance cylinder should be occasionally swabbed with cylinder oil.

Tug Boats.—Tug boats, ferries, and other craft, which have fresh-water supplies available, usually run their engines non-condensing and use cylinder oil in their cylinders.

A satisfactory oil for the engines of these boats, using saturated steam, would have the following general specifications:—

(*a*) Viscosity at 212° Fahr.	140 to 150.
(*b*) Flash	525° to 550° Fahr.
(*c*) Compounded with	5 per cent. acidless tallow oil.

Superheated Steam.—Marine engines, using superheated steam, should be supplied with cylinder oil, because there is very little water of condensation in the high and intermediate cylinders to furnish lubrication.

These ships usually have a steam pressure of about 250 to 275 pounds per square inch at the valve chest. This would give a steam temperature for 265 pounds of 411° Fahr. The steam is passed through superheaters and given about 50° to 75° superheat, making a maximum temperature at the valve chest of 486° Fahr. Therefore an oil of the following general specifications will give satisfactory lubrication:—

(*a*) Flash over 600° Fahr.
(*b*) Viscosity 275 to 320 at 212° Fahr.
(*c*) No compound.

Lubrication of Naval Engines.—In the navy, ships having reciprocating engines of the latest type are lubricated in the following manner: All working parts of main engines, except the "valve links" and "valve stem guides," which are efficiently lubricated by combination sight and wick feed oil-distributing boxes located on the engine, are lubricated by forced-feed lubrication through a suitable system.

The "cross-head guides" are provided with both gravity and forced-feed systems.

High-pressure Marine Cylinders.—Piston valves are almost invariably used for the high-pressure cylinders, and very often piston valves are also used on the intermediate cylinders of triple-expansion engines.

Lubrication of Marine Engine Bearings.—The main shaft bearings are usually cored and provided with pipes, so that water may be circulated through the bearings to keep them cool.

Thrust Bearings.—The most important bearing on a ship is the "thrust bearing." This bearing is the hardest to keep cool. The whole thrust, or power, of the engine that is available to propel the ship is exerted against this bearing.

The thrust bearing is secured to the frame of the ship, "abaft" the engine. It consists of a metal case and cap, which contains a number of babbitt faced, horse-shoe shaped yokes, which are separated by open spaces. The shaft is equipped with a number of collars, which fit into the spaces between the yokes of the bearing, and the faces of these collars bear against the babbitted faces of the "yokes."

The top of each yoke is equipped with an oil pocket, and an oil feed leads from it to the wearing surfaces. A small piece of wool waste is usually kept in this pocket, or "oil boat," as it is called, to regulate the feed of the oil.

The lower part of the bearing is so arranged as to form an oil reservoir, which will contain a supply of oil, or oil and water, so that the collars will dip their lower parts into the oil and carry it up to the bearing surfaces. While the use of water is an old custom, it really defeats the very purposes for which it is intended, as is noted in the paragraph below.

Effect of Water and Oil Mixtures on the Efficiency of Lubrication.—The curve shown in Fig. 77 illustrates, from the results of actual tests, the effect on the friction of a bearing when it was lubricated with varying percentages of water and oil. The bearing was run at a thousand revo-

lutions per minute and with a constant bearing cap pressure, until, at 30 per cent. of water in the mixture, the film broke and the bearing overheated, necessitating a decrease in the speed to 800 R. P. M. The temperature of the bearing cap was maintained at 150° Fahr.

The curve clearly shows that water mixed with oil and used for lubricating purposes, increases the friction of the bearing and should be a strong argument against this practice, except in extreme cases.

Turbine-driven Ships.—On a turbine-propelled ship, the lubricating oil in the system should be circulated for at least 20 minutes to a half hour,

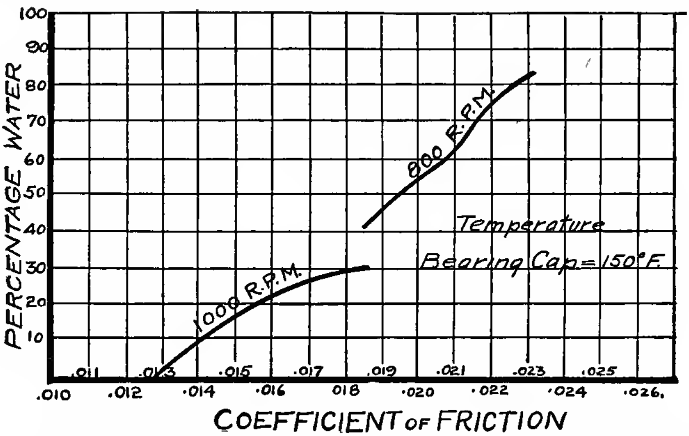


FIG. 77.—Curve showing the effect on the coefficient of friction produced by various mixtures of oil and water.

through the bearings, after the turbines have been shut down. This will clear the bearings of any water and thus prevent corrosion.

Very often, corrosion, which is blamed on acid supposedly contained in the oil, is really caused by water which has been allowed to remain in the bearings, due to shutting down the oil pump too soon.

The lower part of the bearing acts as a settling tank in this case, allowing the water to separate from the oil and come into contact with the surfaces of the journals.

Lubricating Systems.—A typical naval torpedo boat lubricating system may be described as follows:—

The engines are used up to 16 knots per hour, and then the turbines are used. The steam pressure is about 250 pounds. No cylinder oil is used.

Lubricating oil for the thrust bearings, turbines, and engines is supplied by a forced lubricating system. The course of the oil is from the bearings, to a settling tank, to the cooling tank, and then, under 10 pounds pressure, to the bearings.

The oil leaves the bearings at about 100° Fahr. and re-enters them at about the temperature of the sea-water. The oil is cooled by passing it through pipes, surrounded with sea-water, while within the oil pipe is a smaller pipe through which water is also circulated, thus cooling the oil from both sides.

The propeller shaft is direct connected and turned at 600 R. P. M. (approximately) when running at full speed.

Marine Lubricating Oils.—Marine engines are generally equipped with wick feeds, and are lubricated with a highly compounded engine oil, having a high viscosity and good "lathering" properties when in contact with water.

Blown rape-seed oil, or lard oil, is used to compound with mineral oil to manufacture marine engine oils, the object being to secure a good emulsification and lathering effect on the moist surfaces. This custom has been so firmly established in marine practice that it is very difficult to change it. There are, however, many straight mineral oils, particularly heavy paraffine oils, manufactured to-day that will give complete satisfaction for this class of work, staying on the rods even though considerable moisture is present.

Marine engine oils that are compounded with blown rape-seed oil should be examined as to their staple compound qualities. Due to the difference in gravities between petroleum oils and blown rape-seed oil, there is always a tendency for the rape-seed oil to separate out on standing, particularly in a warm place. Barrels containing this oil should be well rolled before they are opened and the contents removed, to insure a uniform percentage of the rape-seed oil throughout the mixture.

The following specifications give the general tests of typical marine engine oils:—

Paraffine Base Mineral Oil:	Asphalt Base Mineral Oil:
(*a*) Vis. at 100° Fahr. ..... 580 Say.	(*a*) Vis. 700 at 100° Fahr.
(*b*) Gravity .... 22.5° B.	(*b*) Gravity 18.5
(*c*) Flash .... 395° Fahr.	(*c*) Flash .... 350° Fahr.
(*d*) Compounded with 25 per cent. Blown Rape.	(*d*) Compounded with 15 per cent. Rape.

Paraffine Base Mineral Oil:		Paraffine Base Mineral Oil:	
(*a*) Vis. at 100° Fahr.	350 Say.	(*a*) Vis. at 100° Fahr.	380
(*b*) Gravity	23.5° B.	(*b*) Gravity	23° B.
(*c*) Flash	470° Fahr.	(*c*) Flash	470° Fahr.
(*d*) Compounded with 15 per cent. Extra No. 1 Lard Oil.		(*d*) No compound used.	

Notes on Amounts of Oils Used by Different Classes of Vessels.—The average river tug, with 150 to 200 H. P. engines, will use about five gallons of cylinder oil per month and about fifteen gallons of engine oil.

A moderately new steamer in the coasting trade, having a three-cylinder, triple-expansion engine (25 x 41½ x 68 x 42), 2820 I. H. P., steam at 170 pounds pressure, and a net tonnage of 1994 tons, gave the following results in gallons of oil used per mile (*nautical*) :—

Gallonage Per Mile

Number of miles run	.2850
* Mean gallonage marine engine oil used per mile	0.0655
Mean gallonage cylinder oil per mile	0.00314
Mean gallonage dynamo oil per mile	0.00346

* Note.—The above figures are merely given as an indication of the relative amounts of oil used in this class of service and are subject to considerable variation in practice. The marine engine oil used had a viscosity at 100° Fahr. of 580° Saybolt, and was a rape compounded oil having 20 per cent. compound. The above ship was equipped with two blower engines above the boilers, which used an excessive amount of oil.

The same ship was lubricated with a straight mineral oil and gave the following results :—

Number of miles run	.8550
* Mean gallonage mineral oil used for engines and blowers	0.069
Mean gallonage cylinder oil per mile	0.0036
Mean gallonage dynamo oil per mile	0.0036

* Note.—The marine engine oil used was a straight mineral, paraffine oil of 375° Vis. at 100° Fahr., and cost, at the time the test was run, ten cents per gallon less than the rape compounded oil in the previous test. The saving is apparent. A great saving, in the average cost of oil for any ship, can be made by using straight mineral engine oil instead of a compounded oil, provided the engineer of the ship can be made to coöperate with the oil company and forget his prejudice against the uncompounded oil. There is absolutely no reason for the continued use of rape oil in marine engine oils, and the high cost of this oil should stimulate investigations and tests looking towards its discontinuance. It is particularly unsatisfactory for use with wick feeds, and yet ship engineers continue to go through the disagreeable operation of removing gummed wicking from the feeds and cleaning the tubes, rather than depart from their old customs and carefully try out the mineral oil.

TYPICAL TESTS, SHOWING COMPARATIVE MILEAGE PER GALLON OF OIL OBTAINED IN THE MERCHANT AND OTHER MARINE SERVICE

Ship	Description of equipment
"A"	Triple-expansion, 28 x 45 x 72 x 54. 381 N. H. P. Working boiler pressure, 185 pounds per square inch. 3500 I. H. P. 1987 net tonnage.
"B"	Triple-expansion, 28 x 38 x 74 x 54. 402 N. H. P. Boiler working pressure, 160 pounds per square inch.
"C"........	Two-cylinder engine, 38 x 74 x 54. Gauge pressure, 110 pounds per square inch.
"D"........	Three-cylinder, triple-expansion, 25x41½x68x42. 300 N. H. P. 2820 I. H. P. Working steam pressure, 170 pounds per square inch. 1994 net tonnage.

Running Test on Above Ships

Ship	Service	Mean mileage	Gallons engine oil per mile	Gallons cylinder oil per mile	Gallons dynamo oil per mile
"B".......	North Atlantic......	1632	.04232	.006437	.00491
"A".......	North Atlantic......	1243	.04680	.005450	.00458
"C".......	North Atlantic......	953	.03887	.002440	.00211
"D".......	South Atlantic......	950	.06550	.003140	.00346

NOTE.—The oil used for the main engines was a rape compounded engine oil, having 20 per cent. rape and a viscosity of 575 Say. at 100° Fahr.

The cylinder oil was used for swabbing the rods and was a straight mineral oil of 145 Vis, at 100° Fahr.

The dynamo oil was classed as a crank-case oil for the high-speed, direct-connected lighting engine.

Wick-feeds, Standard.—One of the largest operators of vessels uses the following schedule of wicks for wick-feeds:—

For steaming 6 knots per hour .... 3 strands
For steaming 10 knots per hour .... 4 strands
For steaming 14 knots per hour .... 8 strands

When steaming at 14 knots and over, an extra set of 10 strands is used for the crank-pins only.

Lubricating Conditions on a Battleship.—The following data were found to be the average for the new types of dreadnoughts:—

Average engine-room temperature .... 92° to 95° Fahr.
Average injection water temperature to bearings (water-cooled) .... 79° to 84° F.
Average R. P. M. .... 83.5 for 14 knots
34 for 6.2 knots

Comparison of the Amounts of Straight Mineral Marine Engine Oil and Rape Compounded Marine Engine Oil Which Will be Fed by a Wick-feed under Normal Running Temperature.—A test was made to

determine whether the amount of oil fed by a marine wick-feed would be increased, if a straight mineral engine oil was used instead of a rape compounded marine engine oil.

The amount of oil fed at ordinary temperatures was, of course, greater with the straight mineral oil than with the compounded oil, but on a marine engine the oil box is usually fixed to the side of a steam cylinder, and the oil is kept at a high temperature. This temperature averages between 160° and 180° Fahr.

Fig. 78 shows the apparatus used in making the test. " A " is the oil-containing box. " B " is an electric heating coil, which kept the oil at a temperature of 170° Fahr. " C " – " C ′ " are two glass tubes containing the wicks, which were made in two different plaits (one composed of four wicks and the other of six wicks). " D " – " D ′ " are graduated cups which measured the cubic centimetres of oil fed per hour. " T " is a thermometer for checking the temperature of the oil in the box.

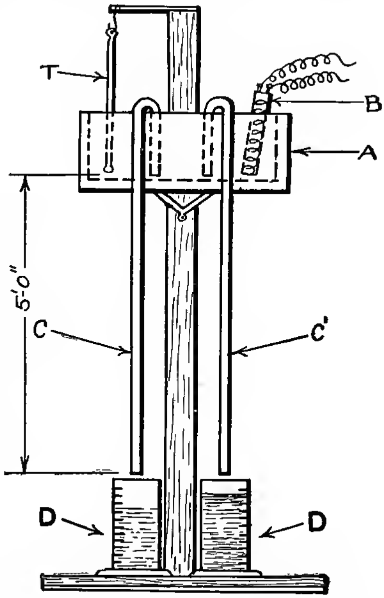


Fig. 78.—Apparatus designed to compare the rates of feed for wick-feeds supplied with compounded and uncompounded oils.

The tubes were made 5 feet long, from the top of the siphon to the bottom of the tube. (This is the average length of feed for the medium-sized boat.)

The results of several tests showed that for different numbers of wicks, as described, and a wide range of room temperatures, the amounts of the compounded oil and uncompounded oils fed were about the same, when the working temperature in the box was the same, and the same number of wicks was used.

The compounded oil consisted of 20 per cent. rape oil, 80 per cent. petroleum oil. Vis. at 100 = 690° Saybolt.

The mineral engine oil had a viscosity of 465° Saybolt at 100.

Knots and Nautical Miles.—The " Nautical Mile," which is used for sea measurements, is equal to 6080 feet, and is thus about 15 per cent. longer than a statute mile.

A "Knot" is not a distance, but a rate of speed, which is one nautical mile per hour. The term "knots per hour" is incorrect and should never be used.

Marine Lubricating Reports.—The large steamship companies require reports from the engineers of their various ships, to be rendered after each round trip, showing the oil on hand, oil used, and the mileage made. The mileage reported is supposed to be corrected to correspond with any alteration in the ship's regular course.

If the steamship company has a contract with an oil company to lubricate its ships at a fixed rate per mile, a duplicate report is sent to the oil company for its records. The large ship-owning companies keep tabulated records of their cost of lubrication per mile for their various ships. A specimen report now used by a well-known steamship company, having a "mileage contract" with an oil company, is shown below. This report is made in triplicate. The first copy is white, the second is pink, and the third is yellow. One copy is retained by the ship's engineer, one is sent to the marine superintendent's office, and one copy is sent to the oil company.

LUBRICATING MILEAGE REPORT

STEAMSHIP ____________________ VOYAGE NUMBER ____________

DATE SAILED ____________ DATE RETURNED ____________

	Cylinder Oil	Marine Engine Oil	Dynamo Oil Turbine Oil	Crank-case Oil
Gallons oil on hand from voyage number (____________)....				
Gallons oil received date (____________)........				
Total gallons on hand sailing......				
Gallons oil used voyage number (____________)...........				
Gallons oil carried ahead.........				
Total miles run on voyage number (____________)...........				
Gallons of oil used per mile.......				

Signed, Chief Engineer ____________

Naval Oiling Systems.—The latest types of torpedo-boat destroyers in the United States Navy are equipped with turbines arranged on two shafts. The cruising turbine shaft is geared to the forward end of the starboard shaft. The reduction ratio is about 7 to 1. The L. P. ahead and astern turbines are on the starboard shaft.

A Metten Clutch, which is designed to uncouple the reduction gear from the main turbine shaft, is placed between the reduction gear and the L. P. turbine. This clutch uncouples the reduction gear from the main shaft, when the revolutions exceed a speed corresponding to about 22 knots. The H. P. ahead and astern turbines are on the port shaft.

The lubricating system of the ship just described consists of two oil pumps and one oil cooler of 210 square feet of cooling surface. Forced-feed lubrication is supplied to all main bearings, thrust bearings, reduction gear, and main circulating engine bearings. The main circulating pump has a separate oil pump driven from an eccentric strap. A small plunger pump supplies oil-pressure to the Metten clutch and is driven by a reduction gear. One oil drain tank of 205 gallons capacity, a main storage tank of 550 gallons capacity, and two oil-settling tanks of 200 gallons are included in the system. Each bearing is fitted with thermometers, observation boxes, and regulating cocks.

The latest battleships are equipped with a lubricating system as follows: All working parts of the main engines, except the valve stem guides and valve links, are fitted with forced-feed lubrication. There are two complete and distinct systems, the starboard and the port. There is a connection between the two, for emergency. Each system consists of three pumps, two 500-gallon tanks for storage, one 500-gallon oil supply tank, and one 500-gallon oil-settling tank. The entire engine is enclosed by a galvanized sheet steel casing to prevent splashing and waste of oil.

The operation of the system outlined above is as follows: One pump draws the oil from the supply tank and discharges to the main engine, thrust bearing, and main circulating pump engines that are on its side of the ship. Holes in the caps of the main bearings permit of the entry of the oil to the circuit. There is an annular groove in the centre of each main bearing, which aids the proper distribution of the oil, part of which lubricates the bearing, and the excess passes out through a radial hole in each journal, in the wake of the groove to the crank-shaft holes, which

are axial. From the axial holes the oil is forced through radial holes to the eccentric straps and crank-pin centre holes, and out through radial holes to the outer surfaces of the crank-pins. The excess of oil from the crank-pins passes up through the connecting rods, to the cross-head bearings and guides.

The escaping oil is drained to the crank-pit, collected in the drain-well, and pumped by the second pump through the filters to the main supply tank. The third pump is used for the auxiliaries. The system is operated at about thirty pounds pressure.

The valve links and valve stem guides are lubricated by combination sight- and wick-feed oil distributing boxes located on the main cylinders. The axial holes in the crank-pins of a ship having two main engines, which developed 24,800 H. P. at 125 revolutions per minute, are about 8 inches in diameter, and the pins themselves are about 19½ inches in diameter and 21 inches long.

Oil Coolers.*—An important part of the lubricating system for all ships fitted with forced-feed lubrication is the oil cooler. A typical installation found on a torpedo-boat destroyer may be described as follows:—

Capacity per hour	3000 gallons.
Film space	$^3/_{16}$ inch
Cooling surface	131.76 sq. ft.
Length over all	7 feet 7¾ inches
Diameter circulating water inlet and outlet	3 inches
Diameter oil inlet and outlet	2½ inches

The circulating water for the oil cooler was supplied from the main pump, and the cooler had a capacity sufficient to cool all the oil in the system from 130° Fahr. to 100° Fahr. when the water was supplied at 60° Fahr.

Storm Oil.—Passenger-carrying vessels usually carry a supply of oil during the stormy months of the year, for use as a wave modifier.

A small quantity of oil skilfully applied may prevent damage to the ship by quelling the action of the disturbed water.

The old method for applying storm oil seems to be as follows: Small canvas bags, which have been punctured with a sail needle, are hung over the side of the ship, so that they trail in the water. These bags hold about two gallons of the oil apiece.

* NOTE.—See Appendix for further description of oil coolers and their uses.

When "running before the wind," the bags are hung from the bow and towed in the water. When "lying to," the bags are suspended in the water, from the "weather bow."

On some ships the oil is ejected into the water by forcing it out through the toilets.

Animal and vegetable oils and engine oil drippings are often used for this purpose. Kerosene is said to be of little use.

Owing to the high prices of animal and fish oils, a petroleum oil that is especially made for the purpose is largely used as storm oil. It should have a fairly good body.

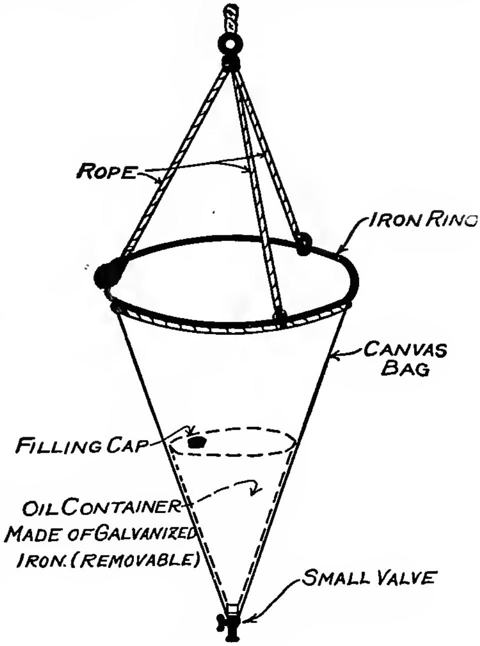


FIG. 79.—Sea Drag.

Sea Drag.—Fig. 79 shows a typical "sea drag," which is provided as part of the equipment of small boats. The drag consists of a cone-shaped canvas bag, which is attached to an iron ring at the top.

A conical-shaped, galvanized iron container is fitted in the lower part of the canvas bag, as shown in the cut. This container holds about a gallon of storm oil, and is provided with a small valve cock at the bottom, through which the oil is allowed to seep into the water when the drag is drawn by the ropes as shown.

This type of drag requires a light, free-flowing storm oil. If an oil of heavy body is used, it will form in drops and will not spread over the surface of the water as is desired. As the size of the valve is about ¼ inch or smaller, it can be appreciated, that if the oil used is too heavy in body there will be difficulty in getting it to flow through the valve into the cold water.

A light paraffine oil of about 150 Vis. at 100° Fahr. will give good results.

General Rules of the Supervising Inspectors.—The Supervising Inspectors have made the following rules for boats on the Great Lakes and inland waters:—

All boats of 3000 to 5000 tons must be equipped with two tanks of twenty gallons capacity for carrying storm oil. These tanks must be fitted with suitable hose connections for getting the oil overboard.

Boats of 5000 tons and over must have two twenty-five-gallon tanks.

Boats of 200 to 1000 tons must have two ten-gallon tanks.

The tanks should both be located forward.

"Slushing Oil."—This oil is used for rough work on winches, etc. Summer or winter black oil is recommended for this purpose.

Signal Oil.—Mineral seal, or 300° oil is usually used for the running lights of ships.

Bunker Lights.—Colza burning oil, which usually consists of about 40 to 50 per cent. of mineral oil, compounded with Colza oil, or cotton-seed oil, is burnt in the small lamps used by the stokers. These lamps are usually made with two burners. The oil used in these lamps must have a high fire test and must burn without smoke. Special lamps are made, that will melt and burn a low melting-point paraffine wax. Sometimes cotton-seed oil is used to compound oil for bunker lights, instead of the Colza oil.

CHAPTER XXVI

MOTORS AND DYNAMOS AND THEIR LUBRICATION

DYNAMOS and motors are usually equipped with self-oiling bearings of the ring or chain-feed types. These bearings are described in the section on "Bearing Lubrication."

Overheating of Bearings.—Overheating of the bearings of dynamos is sometimes caused by unequal magnetic fields between the armature and the poles. This may cause an unequal wear in the bearing and result in causing the shaft to drop down out of alignment.

If the dynamo or motor is equipped with a belt and pulley, excessive bearing pressures may be produced, by an unnecessarily tight belt.

For direct-connected dynamos, overheating of the bearings should immediately result in an inspection of the alignment of the outboard bearing. Stray currents have also been known to have produced trouble in dynamo bearings.

Lubricating Oil.—The same principles govern the selection of an oil for use in the self-oiling bearings of electric machines as is used in the selection of an oil for high-speed engines, having splash-feed bearings. The body of the oil will, of course, vary with the size of the machine. The viscosity should be as low as possible. The oil should have only sufficient viscosity to permit the rings to carry enough of it up to the bearings, to provide ample oil for lubrication, and should be sufficiently free-flowing to permit the free delivery of the oil from the rings to the journal. The viscosity of the oil must also be low enough to permit of its free circulation and cooling when it is in the reservoir.

The reservoirs should be of ample size, so as to permit the oil to have sufficient time to give up the heat brought from the bearing, before it is again carried up by the rings. Very often these reservoirs are entirely too small, and the engineer, in trying to overcome this defect, uses an oil having an unnecessarily high viscosity. Trouble will be periodically experienced from this condition, and it will pay the engineer to enlarge the reservoir. This can often be done by tapping a capped pipe into the lower part of the reservoir; this extra capacity and increased cooling area will usually bring about the desired results.

Notes.—It is a good plan to occasionally draw the oil out of the reservoir and allow it to stand for a few hours in a closed bucket, so that any dirt will settle to the bottom, and the oil can then be replaced in the reservoir.

After an oil has been in a reservoir in active use for some time, it will become darker in color, due largely to metallic wear. This does not affect the lubricating qualities of the oil, however.

Dynamos and motors that are exposed to cold weather should be supplied with a low cold-test oil.

If the viscosity of the oil is too high, it will not spread quickly over the surfaces of the bearing, and in starting up after standing for some time, the oil will have mostly drained back into the reservoir, and will not spread fast enough to prevent excessive friction and heat being generated in the bearing.

Care must be taken to maintain a fairly constant level of oil in the reservoir, so that the rings will be sufficiently immersed.

The action of the rings of hot running bearings should be examined, to determine whether there is any jumping or shaking. Both of these actions are produced by the rings having sharp edges and badly worn grooves.

CHAPTER XXVII

NEWSPAPER PRINTING MACHINERY AND OPERATION

Brief Outline of Newspaper Printing.—The operations of printing a newspaper are rather confusing to the average oil man who enters one of the large city newspaper plants, and in order that the oil trade may have a clear understanding of the purposes of the various machines met with in these plants, the following brief description, which was secured through the courtesy of Mr. Arthur F. Haise, Mechanical Superintendent of the Philadelphia *Public Ledger,* is given.

After the " copy " is written and edited by the Editorial Department, it is sent to the Composing Room, where it is cut into pieces, called " takes "; these are distributed to the operators of the " Linotype Machines " and set in lines of type called " slugs " and delivered to the " make-up " stones, or steel top benches. Here the stories, newsmatter of all sorts, advertisements, and half-tone cuts are assembled and locked into steel frames, called " chases." The chases are then delivered to the stereotype department and a "matrix," which is made of several thicknesses of blotter and tissue held together with a paste, the principal ingredients of which are clay, chalk, and gum arabic, is laid upon the face of the type. It is then covered with a heavy wool blanket and rolled under a large steel roller, which mashes the soft, damp " matrix " into the type form. The " form," with the " matrix " still covering its face, is then placed under a " steam table," which is a table that holds the matrix firmly imbedded in the type form and bakes it with live, dry steam into a permanent, brittle consistency.

The matrix is next placed in a cylindrical casting box and becomes the face of a mould, into which molten metal composed of lead, tin, and antimony is pumped. When the metal has solidified, the curved plate resulting is trimmed and shaved to the proper thickness and is ready for the press. The machine used by most of the metropolitan newspapers to produce these plates is the Junior Autoplate Machine.

The plates are locked onto the cylinders of the presses in pairs, making a complete cylindrical surface and producing two completed papers for each revolution of the presses, which print from a "web " and deliver the papers, folded to half size, at the rate of from 20,000 to 40,000 per hour.

The presses are driven by variable speed motors, ranging from 40 to 80 H. P., through a series of gears, off the main shaft.

The plate and impression cylinders are carried on 3½-inch to 4-inch journals, with bearings on both ends. The journals are of steel, and the bearings are made of brass or phosphor bronze, and are about six inches long. The bearings have oil grooves cut in the upper half.

The cylinder bearings are the most important bearings, from a lubricating standpoint, about the presses. The cylinders weigh about 1200

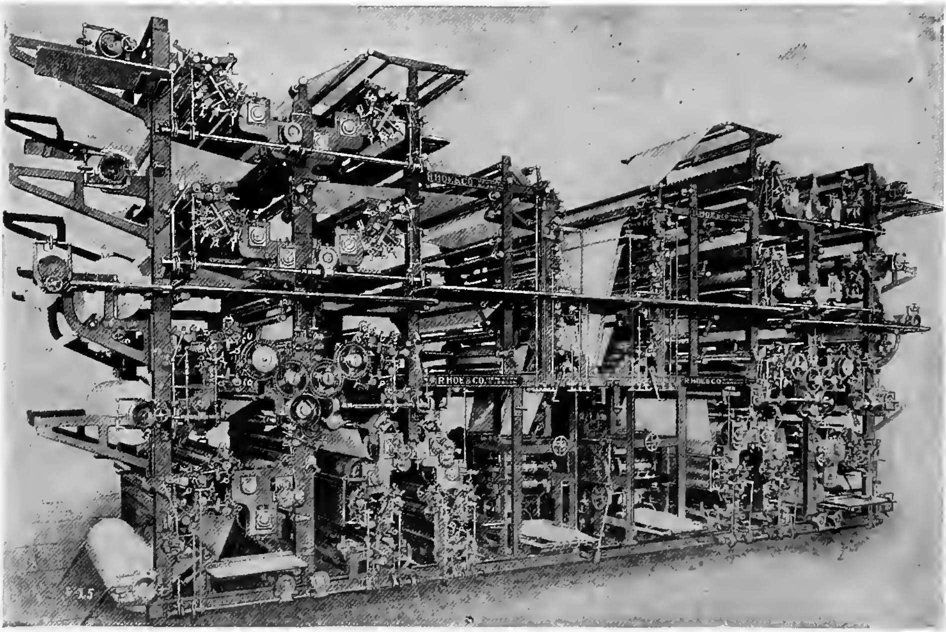


Fig. 80.—High-speed, octuple newspaper printing press, made by R. Hoe & Co.

to 2000 pounds apiece, and each plate (there are eight plates to a cylinder) weighs about 60 pounds.

A standard, high-speed octuple press is shown in Fig. 80 through the courtesy of R. Hoe & Co., of New York.

The gears and other quick-running mechanisms are clearly shown in the cut. The motors are placed in a pit below the press.

Ink is furnished to the printing plates from a fountain or reservoir, on one side of which is a steel roller. This roller is driven by a ratchet and

pawl, and the quantity of ink carried on each revolution is determined by a scraping blade parallel with the roller, the clearance of roller and blade being adjustable by a series of thumb-screws. The ink is transferred from the steel roller to a series of soft composition rollers, which in turn spread a thin film of ink onto the printing plates. Evenness of color is accomplished by vibrating rollers, which are worked by cams. These cams are not enclosed and require continual oiling.

Lubrication.—(*a*) For the cylinder bearings a heavy red engine oil having the following general specifications should be used freely:—

[400 to 500 Vis. at 100° Fahr. (P. B.)], or, [700 to 750 Vis. at 100° Fahr. (A. B.)]

(*b*) For the cams on the vibrating rollers, a very light filtered cylinder stock of about 130° Vis. at 212° Fahr. may be used, or a medium-bodied semi-fluid grease.

(*c*) For the bevel gears at the motor and the cylinder gears on the side, a medium-bodied gear grease should be used (see Index).

(*d*) For the motor bearings, a neutral machine oil of about [160 Vis. at 100° Fahr. (P. B.)] or strictly non-emulsifying oil, of about [200 Vis. at 100° Fahr. (A. B.)].

(*e*) For the worm gear, use a dark cylinder oil of 140 to 150 Vis. at 212° Fahr., or the same oil as recommended for the cams may be used.

(*f*) For the Auto-plate machine, where the temperatures are high, use a filtered cylinder oil as outlined under (*b*).

(*g*) For Linotype machines, use a light-bodied oil as outlined under (*d*).

(*h*) For the Monotype machines, which are usually lubricated with a suet, a fibre grease of high melting-point is recommended.

Roller Wash.—It is necessary to swab off the ink rolls frequently with a light petroleum distillate of about 115° to 130° Fahr. flash test, to prevent the dust from the paper and dirt, which accumulates upon the rolls, making them sticky and causing the paper to adhere to the plates.

This wash is usually applied with a rag, and it should be of such a nature that it will not dry too quickly, and yet it must have good degreasing properties, particularly when it is also used as a wash for the plates. The wash must evaporate completely and must not leave any greasy oil on the roll, since that would cause uneven ink distribution to the plates, with resulting poor impressions. Ink rolls are made of rubber and glycerine, and the roller wash must not cause them to harden.

CHAPTER XXVIII

THE LUBRICATION OF PNEUMATIC TOOLS

Pneumatic Tools.—The most essential and yet the most neglected detail, necessary to obtain the best results from pneumatic tools, is proper and efficient lubrication.

It is difficult to impress the ordinary hammer and drill " runner " with the importance of oiling the drills before they actually run dry. Often the parts will freeze fast and break, due to lack of lubrication.

In large plants " an oiler," or " grease gun man," visits the various machines and renews the oil or grease at frequent intervals. A " grease gun " in the form of a metal syringe is usually used, to inject the lubricant into the machines.

The internal parts of compressed-air machines, such as drills, riveters, mining machines, compressed-air locomotives, etc., are usually small in size and operated at very high speeds.

Drills.—Almost all drills are subject to freezing troubles. This is due to the moisture in the air and the narrow winding passages the exhaust must travel, in order to escape to the atmosphere. Dirt in the air often causes the drill to work badly, and may even stop it.

Fig. 81 shows a sectional view of a " Sergeant " Rock Drill, showing the valve mechanism. This drill is manufactured by the Ingersoll-Rand Company.

Fig. 82 shows a sectional view of a Leyner-Ingersoll Drill. The method of lubricating this type of drill is as follows: An oil chamber is cast beneath the cylinder bore, between the sides of the guide shell.

A plugged opening at the top of the cylinder provides a means of filling the oil chamber with oil.

Small passages are provided between the oil chamber and the cylinder bore. The oil and air in the chamber are thus placed alternately under running pressure and exhaust pressure.

A small amount of the oil is thus fed to the cylinder bore at each stroke of the piston.

The Butterfly Valve.—This type of valve, which is used in the Leyner-Ingersoll and other Ingersoll-Rand types of drills, is an independent valve, since it has no connection with the " hammer."

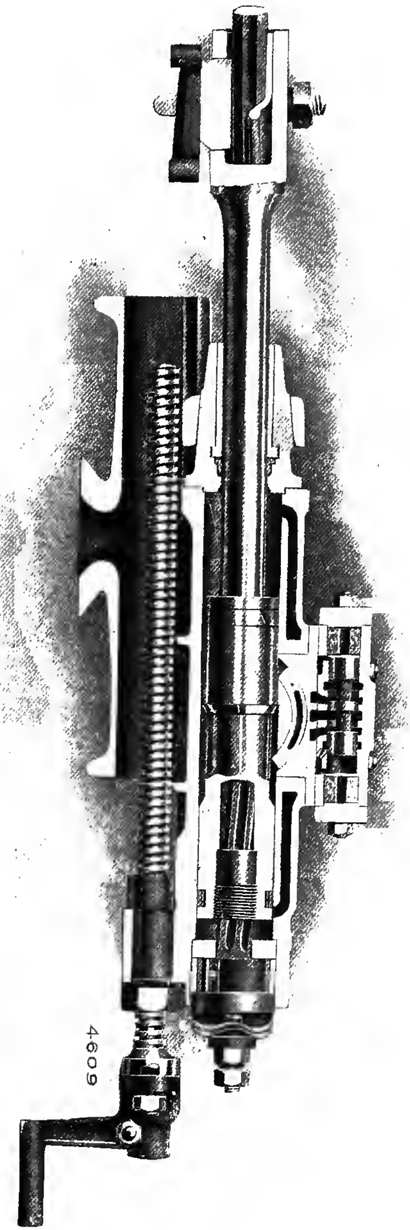


FIG. 81.—Sectional view of Sergeant rock drill, made by the Ingersoll-Rand Company.

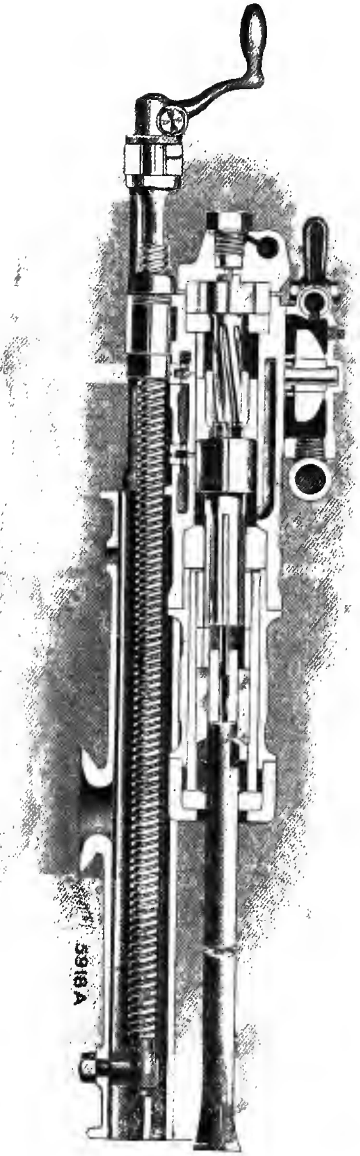


FIG. 82.—Sectional view of Leynor-Ingersol drill, showing mechanism.

The valve is an "air thrown" valve, being operated by unbalancing the air-pressure. It consists of a single piece of steel, shaped to form a cylindrical trunnion with two flat wings, one on each side.

The trunnion is carried in a bore in the valve chest, and the wings are accommodated by a longitudinal groove in the valve chest, which allows of a slight back-and-forth rotative movement. This movement is obtained by the unbalancing of the air-pressure on each of the wings alternately.

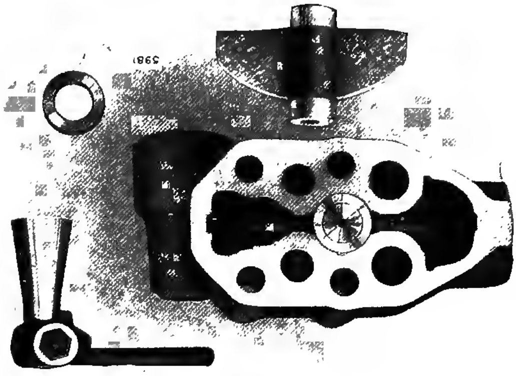


FIG. 83.—Butterfly valve and chest of Leynor-Ingersoll drill.

Fig. 83 shows a Butterfly Valve and Chest.

There is a separate and distinct passage for the air supply and exhaust to each end of the cylinder. This style of valve movement results in a very high speed drill.

Lubrication.—Lubricating oils for use in compressed-air machinery should have a low cold test. The expansion of air from high to low pressures causes it to absorb heat from the metal parts surrounding it, and intense cold is produced in these parts.

A good oil for use on pneumatic drills and hammers, etc., would have the following general specifications:—

(*a*) Viscosity	150 to 200 at 100° Fahr. (P. B.)
	225 to 250 at 100° Fahr. (A. B.)
(*b*) Cold Test	Not above 10° Fahr.

Pneumatic Hammers.—The most important factors in the operation of pneumatic hammers are cleanliness and good lubrication.

The air supplied to the hammers generally contains dust and grit, and unless care is taken, to frequently remove this matter, clogging will occur. It is good practice to immerse the hammer overnight in a bath of benzine and to blow it out under pressure the following morning. The drill should then be lubricated with an oil similar to the oil described above.

Some of the largest plants lubricate their hammers with a petroleum grease in summer. This grease is described in another section of this

book, and may be really compared to a poor cold-test cylinder stock, since its melting-point is about 120° Fahr. This grease is fed to the hammers with a squirt gun. In winter these plants use a filtered cylinder stock, so that the lubricant will not be too stiff, due to the cold. A suitable cylinder stock for this purpose would have a viscosity of about 100 to 110 at 212° Fahr. and a cold test of about 70° Fahr.

For use in very cold weather, a lubricant having a better cold test is required, and a cylinder oil of about 100 to 110 viscosity at 212° Fahr. and 30° to 35° Fahr. cold test is recommended.

Notes.—The inlet openings of pneumatic tools should be suitably screened against the admission of foreign matter to the valve chest.

Rock drills are usually equipped with a " drill oiler," coupled in the air supply, so that the air may be charged with the oil. For use in these oilers, an oil of about 125 Vis. at 100° and 0° Fahr. cold test is recommended.

The great majority of men, who operate pneumatic hammers in the shops, know very little if anything about the construction or maintenance of these tools. It will pay any large plant using pneumatic tools to employ a competent man to look after them, and to see that *" they are properly lubricated "* and returned, when the workmen are through with them.

CHAPTER XXIX

THE LUBRICATION OF RAILWAY LOCOMOTIVES AND CARS

THE lubrication of locomotive driving-wheel and engine truck journals depends upon the oil fed by the sponging in the cellars of the journal boxes.

Fig. 84 shows a typical driving-box cellar and the proper method of packing it, to prevent the ends of the waste from being drawn up between the journal and the brasses, which would result in a hot box. As shown

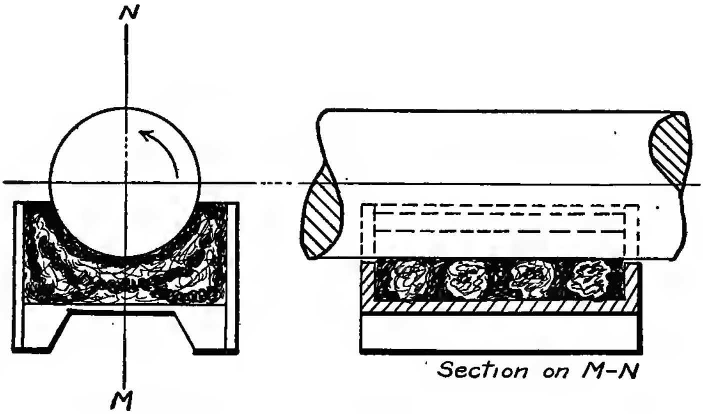


FIG. 84.—Method of packing locomotive driving-box cellars.

in the figure, the packing is composed of several separate portions which are placed in position across the cellar. The packing is thus separated for two reasons, namely: (*a*) To make the operation of examining the box easy, without tearing the entire packing to pieces with the tool; and (*b*) to reduce the possibility of the waste being carried up by the journal, as described above. The tops of driving and engine truck boxes should be packed with a thin covering of cotton waste, and, if possible, a thin, sheet-iron covering should be made to slide over the box. The cotton waste serves to hold the oil in the cellar and to gradually feed it to the journal. It also aids in excluding dirt and grit from the bearing.

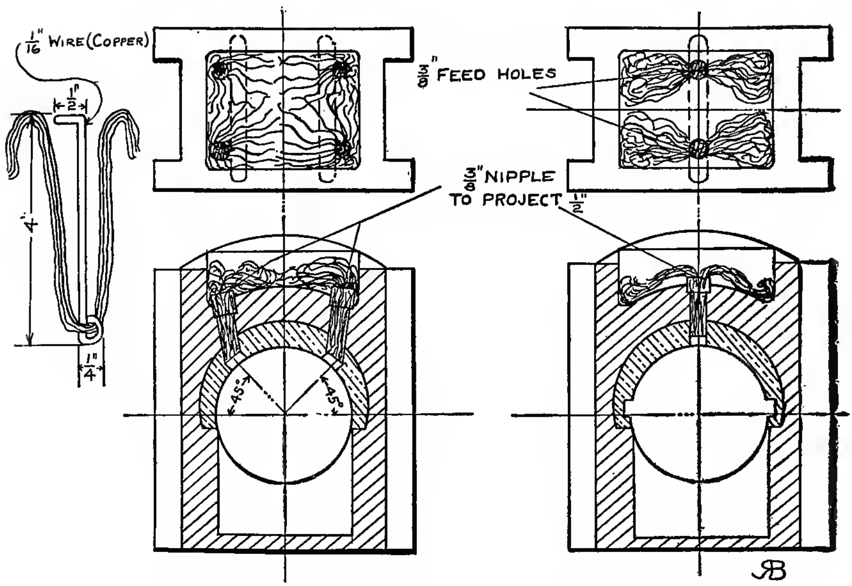


FIG. 85.—Method of arranging wick feeders at the top of locomotive driving boxes.

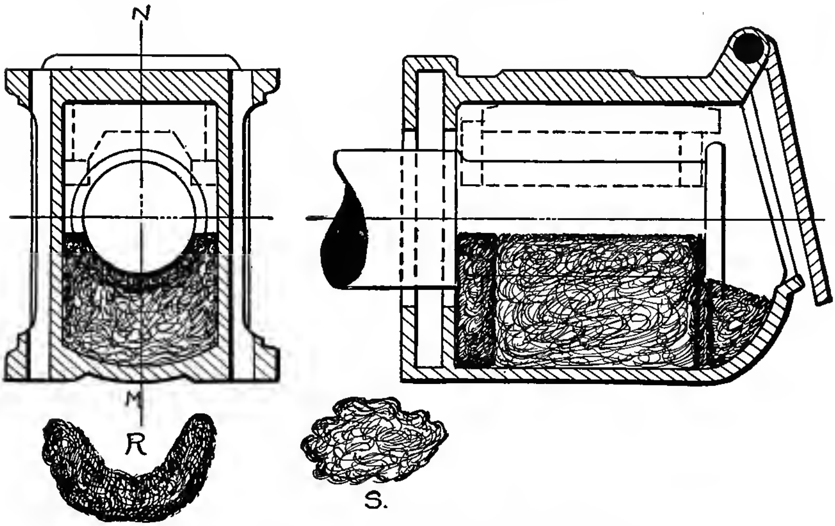


FIG. 86.—Method of packing railway car journal boxes.

Fig. 85 shows the general arrangement of the cotton waste and oil wick feeders for the top of a typical driving box. It is recommended that a piece of woollen yarn, attached at one end to a $^1/_{16}$-inch copper wire, be

inserted in the oil hole as shown, to act as a wick-feed for the oil. This will prevent dirt from entering and can be adjusted to regulate the feed. The wire provides an easy method of inserting and removing the wick-feeds.

The journal boxes of car journals are packed as shown in Fig. 86. The packing is first made into a roll and packed tightly around the back of the box to retain the oil and exclude dust. The rest of the box is packed with loosely formed packing, placed sufficiently firm underneath the journal to prevent its settling away, due to the shocks and jolts produced, as the truck moves along the track. The packing should never extend above the centre line of the journal. In the front end of the box, a separate piece of packing should be placed, extending not more than a half inch above the lower edge of the journal collar. This packing serves to hold the other packing in its proper position, under the journal.

Journal Oil.—The oil used in freight-car journal boxes should have the following approximate specifications:—

	Summer (*May 1 to October 1*)	Winter (*October 1 to May 1*)
Cold test	Not above 32° Fahr.	Not above 10° Fahr.
Viscosity	200 to 220 at 130° Fahr.	160 to 170 at 130° Fahr.
Flash	Above 300° Fahr.	Above 280° Fahr.

Tarry Deposit.—The oil must not show more than 5 per cent. tarry deposit, when mixed with 88° B. gasoline, in proportion of 1 to 19, and allowed to settle.

A typical passenger car journal oil should have the following general specifications:—

Summer	Winter
One part summer car oil as specified above for freight cars.	Two parts winter car oil as specified above.
Two parts 500° cylinder stock.	One part 500° cylinder stock.
One part of extra lard oil.	One part extra No. 1 lard oil.

Engine and Tender Truck Oil.—Engine oil for use in engine and tender truck boxes and for general locomotive bearings should have the following specifications:—

(*a*) The flash test should be above 300° Fahr.

(*b*) The fire test should be above 400° Fahr.

(*c*) There must not be more than 5 per cent. tarry deposit with the gasoline test.

(*d*) It should contain not less than 20 per cent. of extra No. 1 lard oil.

(*e*) It must not contain more than ½ of 1 per cent. free acid.

Notes.—The lubrication of "driving crown brasses" and "driving axle journals" is more important than the lubrication of any other part of the locomotive. The driving axle boxes of locomotives support the weight of the boiler and its fittings, and, due to the conditions existing in locomotive practice and design, such as the gauge of the track, width of the fire-box, etc., the driving axle journals are made as short as possible. As a result they are usually made only as long, more or less, as their diameter. This condition is not found in stationary practice, because the length of journals is not limited, and as a result it is general practice to make the bearings twice the diameter of the journal, in length.

It is therefore evident, that with the enormous weight on the driving axle journals, of many thousands of pounds, and the high rubbing speeds of the journals of fast locomotives, combined with the reduced bearing area, and consequent increased bearing pressure per square inch, the lubricating conditions are severe.

The Care of Railway Journals.—At frequent intervals, the packing in driving and engine truck cellars should be carefully examined. For through passenger locomotives this examination should be made at least once every two weeks, and for local passenger and freight locomotives, once every month.

Journal boxes under locomotive tenders should be oiled and packed according to the methods described for passenger and freight cars. About one thousand miles is the average run for passenger locomotive tenders, for each oiling.

The packing in all journal boxes must be frequently loosened on each side of the journal, to prevent the same surface of the packing from remaining in contact with the journal too long, and becoming covered with a hardened glazed surface, which would prevent the proper feeding of the oil to the bearing. Special tools are designed to enable the inspector to carry out these loosening, or turning, operations.

Preparing Waste for Use.*—Railroad waste is prepared at a central distributing point and is delivered to the oiling stations, ready for use.

The usual method of preparing the waste is as follows: It is first immersed in the oil for two days. The waste is then placed in thin layers

* Note.—For waste specifications see Appendix.

on wire racks and allowed to drain, until it contains about 4¾ pounds of oil per pound of dry waste (approximately five pints).

Valve Oil for Locomotives.—In the past, locomotive cylinder oil usually consisted of a good quality cylinder stock, compounded with about

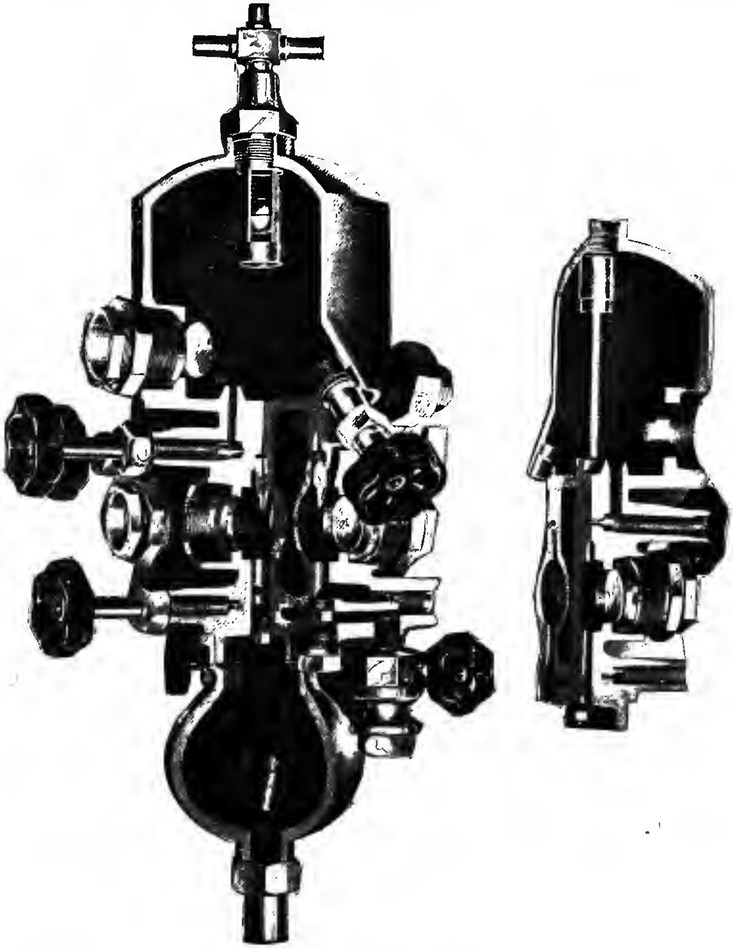


FIG. 87.—Sectional view of the Michigan Triple-feed Bull's-eye Locomotive Lubricator, made by The Michigan Lubricator Company.

20 per cent. extra lard oil. Specifications used by one of the large railroads are as follows:—

(*a*) Flash about 525° Fahr.

(*b*) Fire-point not below 600° Fahr.

(*c*) No tarry deposit when mixed, 1 to 19, with 88° gasoline.

(*d*) Acidless animal oil not less than 15 per cent.

Several of the larger roads have cut the percentage of animal oil in the cylinder down to as low as 5 per cent.

A typical cylinder stock for use in the cylinders of engines using superheated steam will have the following general specifications:—

(*a*) 200 to 210 Vis. at 212° Fahr.

(*b*) Flash, 590° Fahr.

(*c*) Fire over 625° Fahr.

(*d*) Gravity, 24 to 26° B.

(*e*) Pure mineral.

Cylinder Lubricators.—Fig. 87 shows a sectional view of the widely used locomotive cylinder lubricator made by the Michigan Lubricator Company, of Detroit, Michigan. The triple-feed lubricator provides a feed for each cylinder and one for the air pump.

In some types of small, simple, direct locomotives, a separate lubricator is provided for the air pump.

Locomotive lubricators are also made with four feeds, to supply two cylinders and two air pumps, or two high-pressure cylinders and two low-pressure cylinders. Five feed lubricators, for use with superheated steam, Compounded or Mallet type locomotives, provide four feeds for valve and cylinder lubrication and a fifth for the air pump.

FIG. 88.—Michigan Automatic Steam Chest plug, made by The Michigan Lubricator Company.

Locomotive lubricator connections usually straddle the throttle, and "chokes" must be provided to maintain the balance of the lubricator. Sometimes these "chokes" are in the cylinder feeds, within the lubricator, or they may be in the automatic steam chest plugs, which have an automatic ball valve, giving a large area when the valve is opened, but reduced when the valve is closed. A "Michigan Automatic Steam Chest Plug" is shown in Fig. 88.

Starting.—When preparing the locomotive before running, the cylinders should be drained of water, through the cylinder cocks. Do not give the engine full throttle, in starting, as all of the condensed steam will be carried into the steam chests and cylinders, tending to wash off the oil and cause waste

Irregular Feeding.—If the lubricators feed irregularly, examine the choke plugs, for enlarged openings. If the feed of the lubricator increases, when the throttle is closed, the lubricator is out of order and should be immediately returned to the shop.

NOTES ON CAR LUBRICATION

Causes of Poor Lubrication on Journal Car Boxes.—

(*a*) The waste may have insufficient oil in it.
(*b*) There may not be enough waste in the cellar.
(*c*) The waste may not be resilient.
(*d*) The waste may not be evenly saturated with oil.
(*e*) The oil may have been washed out of the cellar by rain.
(*f*) The oil may have frozen, which would stop the feed.

CHAPTER XXX

ROLLING MILLS AND THEIR LUBRICATION

Rolling Mills.—The production of rolled shapes of iron and steel is carried out in " rolling mills."

A " rolling mill " is composed of a train of " rolls," which are in turn composed of " roll stands." A " roll stand " consists of at least two rolls set between and carried by " housings." The rolls are made of chilled iron or steel, and are cylindrical. They are set one above the other, with their axes parallel and held in housings, so that there is a fixed space between them.

Roll Drive.—The rolls are driven by motors or steam engines, through transmission gears, so connected that the rolls rotate in opposite directions. The gears are connected to the rolls and to the motive power by means of " spindles," which are short shafts connected by " coupling boxes."

Roll Necks.—The rolls are provided with journals or " necks," as they are called. These " necks " are nearly as large as the rolls themselves.

Rolling Processes.—Iron and steel are rolled at a temperature that is high enough to soften and render the metal pliable. The rolling operation consists in passing the tough, pliable material between the rolls, and as the thickness of the material is greater than the space between the rolls, the result produced is compression and elongation.

Roll Screws.—On the tops of the necks of the rolls are placed bearings, on which rest the ends of the roll screws, which are used to bring the rolls closer together, or further apart, as desired.

Roll Pressures.—When a piece of steel or iron is being rolled, the pressure on the bearings and necks is tremendous, and good lubrication is therefore necessary.

Types of Mills.—There are two types of rolling mills, namely: " Reversing " and " Non-reversing " mills.

"Reversing mills" have only two rolls—set one above the other. The mill is stopped after each "pass" and the power is reversed, so that the material may be rolled back in the opposite direction. The engines of these mills are very heavy and powerful, because no fly-wheel can be used to store up the energy necessary to overcome the overloads.

The "continuous" or "non-reversing" type of mill has three rolls, arranged one above the other. The material is passed between lower and middle rolls in one direction, returning between upper and middle rolls.

"Billet mills," "sheet bar mills," "rod and wire mills," "hoop" and "cotton tie" mills, and 20- to 32-inch sheet mills, are usually built of the continuous type, which has a number of stands of two rolls arranged one behind the other, and which may or may not be driven at increasing speeds, progressively.

Rolling mills are distinguished by the name of the material which they produce. When referred to by their size or rating, the dimension refers to the diameters of the rolls for all types except plate rolls, which are rated by the maximum width that they can roll.

A typical 18-inch bar mill, as manufactured by the United Engineering and Foundry Company, of Pittsburgh, is shown in Fig. 89.

Cold Rolls.—Rolls for rolling rails, bars, rods, structural shapes, etc., are fitted with water pipes, so that streams of water can be kept running over the roll necks to prevent overheating.

Cold neck grease is used for the lubrication of cold rolls. This grease is composed largely of suet or tallow, either plain, or mixed with a petroleum grease. The mixed greases are called "tallow compounds."

Cold neck grease is usually packed directly against the roll necks. It is usually contained in a burlap bag and fed gradually by melting, to the surfaces of the necks.

Hot Rolls.—Rolls for making sheet steel, tin plate, etc., are called hot rolls. No water can be used to cool the necks of these rolls, due to the nature of the work being done, and as a consequence they run at very high temperatures.

Hot neck rolls are lubricated with a petroleum residuum, stearine pitch or wool pitch, thickened with rosin, talc, lime graphite, or other substances. This grease is of so dense a nature that it must be melted by the application of heat before it can be swabbed on the roll necks. Grease for this purpose is called "Hot Neck Grease." Hot neck grease has very high adhesive properties. After using, it is usually collected, and after remelting and settling to remove the dirt, it can be used again.

Drive Gears.—The gears in rolling mills are large and should be lubricated with a medium-bodied "pinion grease." This grease is made of a petroleum residue combined with pine tar. (See Index.)

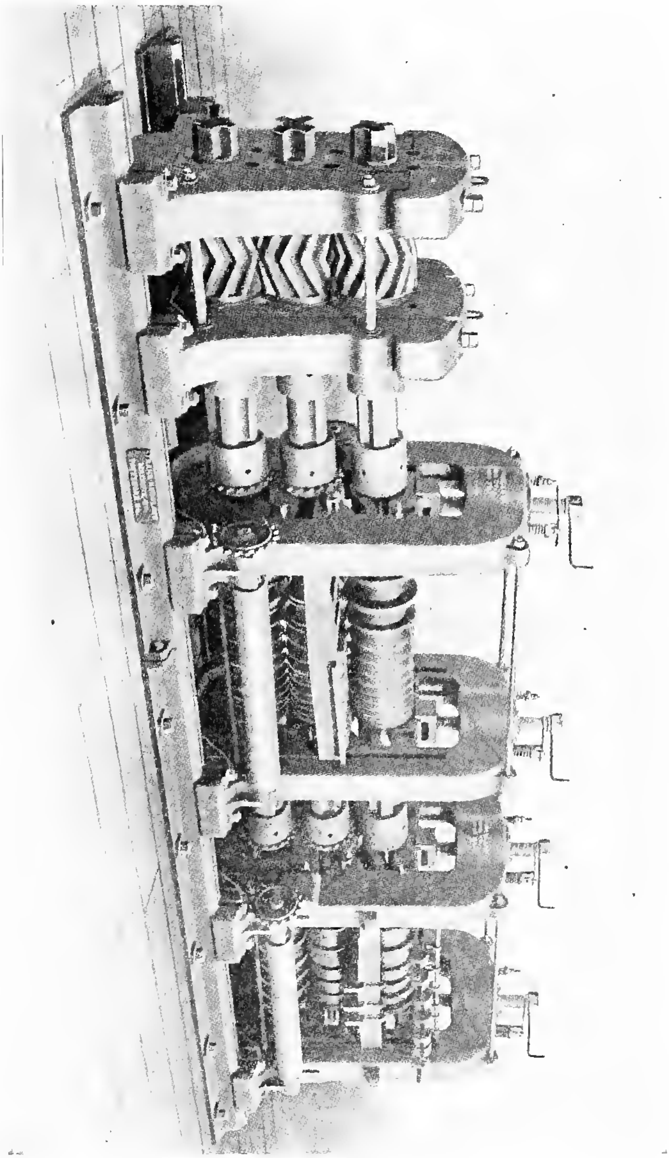


FIG. 89.—18-inch Bar Mill, made by The United Engineering and Foundry Company.

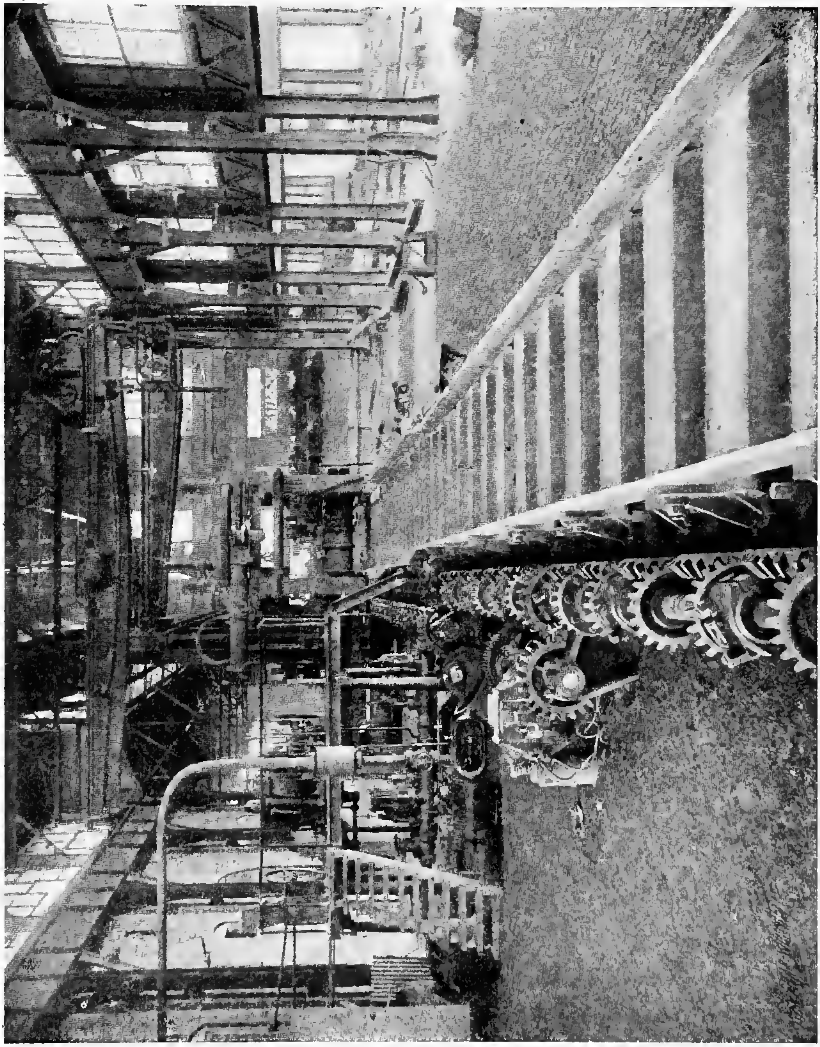


Fig. 90.—A 38-inch Blooming Mill and Tables installed by The United Engineering and Foundry Company.

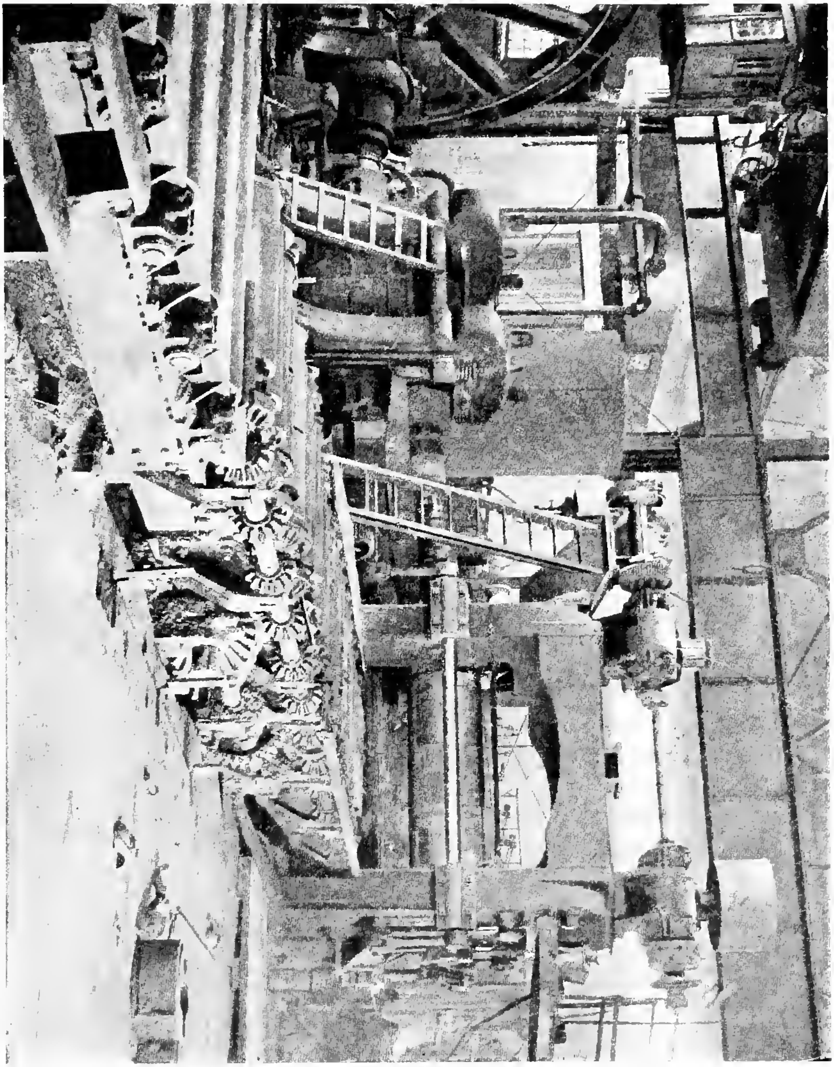


FIG. 91.—84-inch Plate Mill installed by The United Engineering and Foundry Company.

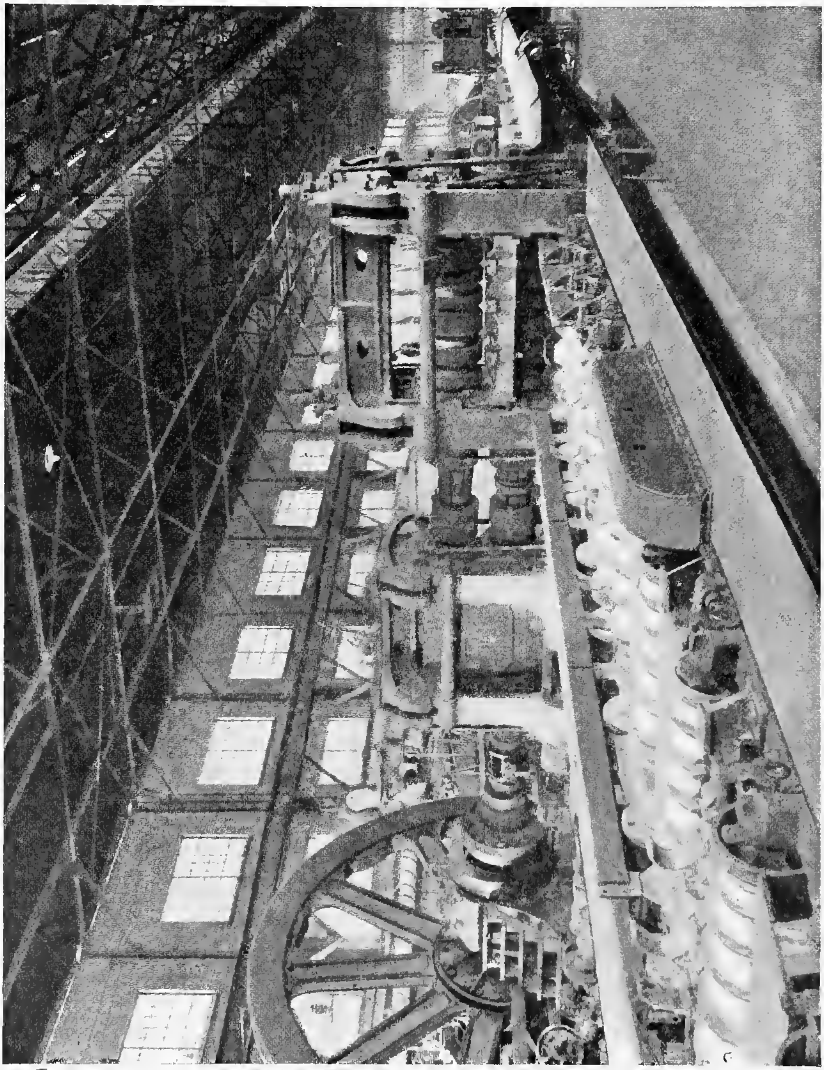


Fig. 92.—28-inch Merchant Mill installed by The United Engineering and Foundry Company.

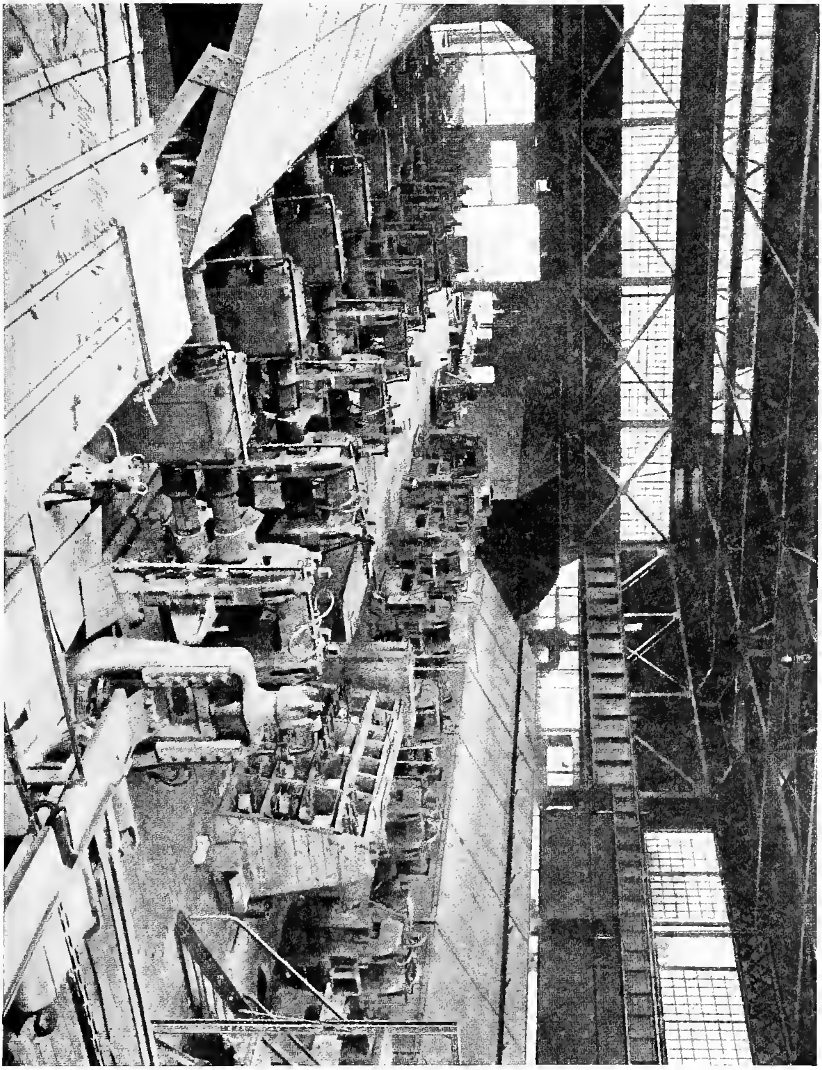


FIG. 93.—View of two Morgan Continuous Mills installed by The United Engineering and Foundry Company.

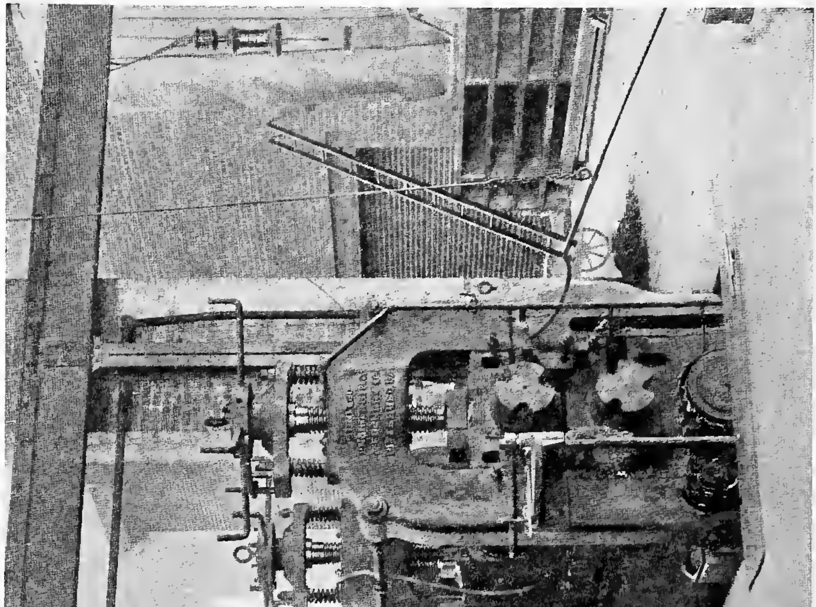


Fig. 94.—Typical 20-inch Merchant Mill installed by The United Engineering and Foundry Company. (Motor Driven.)

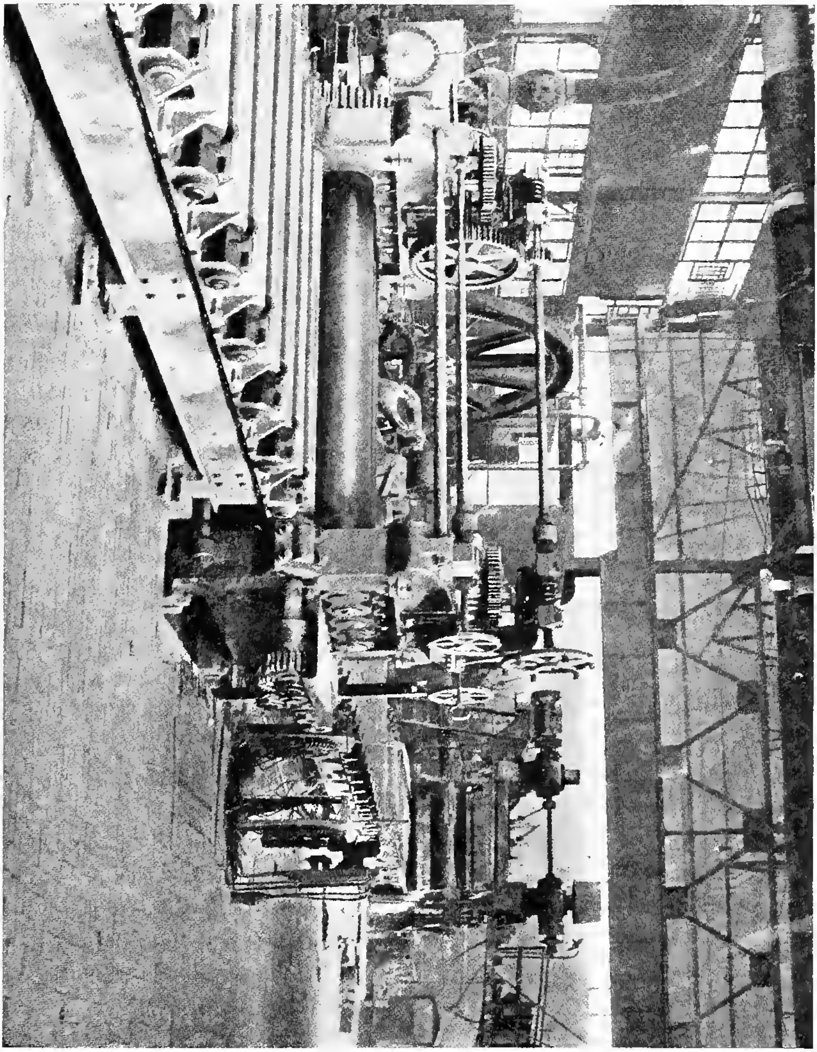


Fig. 95.—100-inch Plate Straightening Machine and 84-inch Plate Mill installed by The United Engineering and Foundry Company.

The small, fast-running gears should be lubricated with a dark gear grease. Usually a brush is used to apply this grease.

Table roll journals, electric cranes, and other similar machinery should be lubricated with a black oil. Surfaces that require lubrication and that are near to soaking pits and hot metal should be lubricated with a very thin pinion grease, or with a black oil.

Dust and mill scale cause the worst trouble in the lubrication of rolling mills, and all bearings should be kept covered.

Typical Rolling Mill Machinery.—Through the courtesy of The United Engineering and Foundry Company, of Pittsburgh, Pa., the following mill installations of their machinery are shown, for the purpose of demonstrating the lubricating conditions to be met with in this class of operations.

Fig. 90 shows a 38-inch Blooming Mill and Tables at The Sharon Works, Carnegie Steel Company.

Fig. 91 shows an 84-inch Plate Mill at the La Belle Iron Works, Steubenville, Ohio.

Fig. 92 shows a 28-inch Merchant Mill in the Duquesne works of the Carnegie Steel Company.

Fig. 93 gives a view of Two Morgan Continuous Mills at the Youngstown Sheet and Tube Company, Youngstown, Ohio.

Fig. 94 shows a typical 20-inch Merchant Mill as installed at The Singer Manufacturing Company, Elizabethport, New Jersey.

Fig. 95 shows the construction of a 100-inch Plate Straightening Machine and 84-inch Plate Mill at the La Belle Iron Company, Steubenville, Ohio.

The above machinery was manufactured by The United Engineering and Foundry Company, of Pittsburgh, Pa.

Other Oils.—"Torch oil" is used by rolling mill employees for their hand torches. This oil should have a good flash test and burn without excessive smoking. A very light bodied paraffine oil may be used.

The usual rolling mill engines operate under very dusty, dirty conditions. The bearings are mostly cup fed and should be supplied with an engine oil of about (250 Vis. at 100° Fahr. P. B.) or (350 Vis. at 100° Fahr. A. B.). The oil should have a good cold test. The cylinders of these engines are usually supplied with fairly wet steam, as the steam piping and separators are often in poor condition. A low viscosity, well compounded cylinder oil is recommended.

CHAPTER XXXI

TEXTILE MACHINERY, OPERATIONS AND LUBRICATION

Textile Mills.—The consumption of power in a textile mill is not divided among a few machines, but is distributed among possibly thousands of spindles, light high-speed machinery, long lines of shafting, many looms, and other machines. The unit friction in any one of the bearings of this light, high-speed machinery may be very small, but it is repeated in many thousands of these bearings, and as a result, the cost of power is a heavy fixed expense in any textile mill.

Cost of Power.—The average cost of power, to manufacture a textile product, has been given by several authorities to average 10 per cent. of the mill selling price of the finished product.

A power saving of 25 per cent. will thus enable the manufacturer to cut the selling price of his product 2.5 per cent., enabling him to secure additional business in competitive selling.

Ring oilers, babbitted bearings, and self-aligning ball bearings have greatly reduced the former heavy friction loads of the transmission shafting in textile mills, and the lubricating engineer will find the most productive field for his efforts, in the improvements resulting from efficient lubrication of the individual machines and spindles.

Brief Description of the Manufacture of Cotton Yarns.—In order that the lubricating engineer may have an intelligent idea of the processes used in the manufacture of cotton yarns, the following brief outline is included in this chapter.

The cotton is taken from the "bale" and dried. It is then cleaned by passing through a series of "picker machines," named in order as follows: (*a*) Automatic Feeder, (*b*) Breaker Picker, (*c*) Intermediate Picker, and (*d*) Finisher Picker. These machines pull the matted wads of cotton to shreds and remove the dirt, sticks, stones, and seeds.

The cotton is now in the form of "batting" on the cylinders. It comes from the finishing picker as "lap."

The "carders" comb the fibres parallel, by means of revolving cylinders, which are covered with a large number of wire teeth. These teeth are called "card clothing." Any "fine leaf," short fibres, etc., is removed by the carders.

The lap is now in the form of a " web " about a yard wide. This web is passed through small " eyes." These bring the lap into narrow bands known as " card slivers." Sometimes, if a very fine, strong yarn is desired, it may be combed in addition to carding, but in most mills this process is passed over.

By " combing " is meant the removal of short fibres known as " waste," so that only the longest and strongest fibres remain.

The " slivers " are now composed of fibres, and a slight pull will bring them straight or parallel. The " drawing frame " is used for this purpose. It consists of a number of sets of rollers, the front roller having a faster speed than the rear rollers.

The " slivers " come from the drawing frame combined as one " sliver." The processes, through which the stock has now been passed, have been designed to arrange the fibres, clean them and make them uniform.

The " sliver " is now again drawn out by the " flyer frames," but in addition it also receives a slight twist. It passes through several of these frames, having the same general construction, but differing in size of the parts. The machines are called " slubbers," " intermediate," and " roving." Each machine draws and twists. The " intermediate " takes the very slightly twisted " rove " from the slubber and gives it more twist, and then passes it on to the " roving machine."

Spinning.—The spinning process consists in drawing out the cotton roving to the desired size and giving it some twist. There are two methods of spinning, known as " ring " and " mule."

The oldest method is " mule spinning," in which the spindles are mounted upon a " carriage," which is moved in and out with reference to the " rolls."

When the spindles are moving away, the stock is being delivered by the rolls, but at little slower rate than the travel of the carriage, so that there results a slight pull. At the same time a twist is given to the yarn, and when the end of the outward carriage travel is reached, the rolls are stopped and the yarn is wound on the spindles as the frame moves in.

" Ring spinning " differs from " mule spinning " in that the mule carriage is replaced by a ring. The ring is connected with a " twiller," which acts as a drag on the yarn. It is shaped like a letter D and made of flat steel wire.

Brief Description of the Manufacture of Worsted and Woollen Yarns—Washing or Scouring.—The wool, after being sheared from the sheep, is sorted, by an expert sorter, into ten or eleven grades of wool.

It contains more or less "yolk," or grease, in it, which must be removed preliminary to working the stock into yarns. This grease is removed in the "scouring machine," which consists of two liquor bowls and one rinsing bowl. The liquor is made of soap and soda ash, and the wool is passed through the first liquor bowl, then through heavy rollers into the second liquor bowl and on into the rinsing bowl.

After the scouring processes, the wool is dried, either in drying machines or in the open air.

The dry wool is harsh and wiry to the touch and must be oiled, before it is worked, to keep it from flying off the cards and to lubricate the wool as it passes through the various mechanical operations of carding.

Oiling.—The operation of "oiling" is usually performed during the "mixing." The mixing process consists in blending two or more different grades of colors or grades of wool.

The wool is spread out on the floor, and layers of the different grades are sprayed with straight, or emulsified, wool oil from a can, as the mix is made up, each layer of the mix being sprayed with the oil.

This oil stays in the wool until it has been made into yarn and woven into cloth, when it is scoured out of the fabric. A satisfactory wool oil will be easily removed from the fabric and an unsatisfactory oil will be removed with difficulty.

When being carded, the room is always kept at a very warm temperature. The wool oil should never be made into soap, because the water will dry out in the warm carding rooms and a dry soap powder will remain in the wool, which would be objectionable.

Usually, in the process of working the wool, it is about two and a half to three months, between the time of oiling until the wool is made into finished cloth.

A prepared water, containing a very weak solution of a good soap, will hold the emulsion much better than water prepared with sal soda, soda ash, or other alkalies, and a weak solution of soap and water will not dry out as quickly as an alkaline solution. The prepared water and the wool oil are mixed in varying quantities to form the emulsion.

When washing the cloth, where hard water is used, rinse water should

be let in to carry the soap off gradually. If the soap is drawn off too quickly, the scum in the lime substance may drop down onto the cloth, and this scum is very hard to remove with clear water.

The alkali in the soap must be in sufficient quantities to entirely saponify the oil, in order that it will wash out easily.

It generally does not require as much soap to remove the oil, if one soaping instead of two soapings, with an intervening rinsing, are used. This is due to the fact that the reduced amount of oil in the cloth allows the fabric to be filled with water, which consequently greatly reduces the strength of the soap solution.

Notes on Wool.—Wool is not true hair, but is much softer, finer, and more wavy, and is covered with very small, overlapping scales. Wool has a great affinity for moisture, and in very damp atmosphere may absorb an amount of water equal to its own weight. The commercial maximum is 5 to 8 per cent.

It is said that diseased fibres, taken from a sheep that has died, will not take their color well. This result is often unjustly credited to the wool oil, by the dyers.

Textile soaps used in scouring are made by treating saponifiable oils with alkali. If the soap contains an excess of alkali, the fibres will be quickly attacked, producing rotten fibres. This is also often blamed on the wool oil.

The lubricating engineer should be prepared to thoroughly investigate any complaints against the wool oils sold by his company, and should therefore make a study of the entire process of making yarns, etc.

Pickers.—After "oiling," the wool is passed through "pickers," which remove the lumps and some of the dirt.

Carding.—After leaving the pickers, the wool is carded. The "cards" are machines having cylinders with sharp wire teeth or pins thickly projecting from their surfaces. These cylinders are usually covered with leather. The wool is usually passed through three sets of "cards," and the room in which these machines operate is kept very warm.

Combing.—The wool, which has passed through the carding machines, is next put through the "combs." These machines straighten the tuft fibres and separate them into long and short lengths, the long lengths being delivered in the form of the "sliver," which is wound onto rollers and is called "top." The short combings are thrown out by the machines

and are called "noils." These noils are not used in the manufacture of worsted yarns, but are used to make woollen and carpet yarns.

The combing machine is very complicated.

Worsted Yarns.—A "worsted yarn" is one having straight fibres. The manufacture of worsted yarns is as follows:—

The sliver is passed through "gill boxes," which are machines containing bars of iron mounted with two rows of teeth, or pins. The bars have screws and are worked between two sets of rollers. The wool enters the first set of rollers and is caught by a "gill"; that is raised and followed by others, as the roll revolves. The "gills" are moved forward on screws in the direction of the other set of rollers.

The teeth or pins in the gills keep the fibres straight. The second rollers are called "draught rollers." These rollers pull the wool through and, by turning faster than the first rollers, a "drawing out" of the wool is also accomplished.

"Gills" are used to produce "worsted yarns."

Woollen Yarns.—In woollen yarn the fibres lie in all directions. The process of making this yarn is as follows:—

It is first carded, no attempt being made to keep the fibres straight. Mule frames then draw, twist, and reduce its thickness.

The "gills" and "combs" are omitted and the yarn is of a rough, fuzzy nature.

Lubrication of Yarn-making Machinery.—For preparatory woollen, worsted, and cotton yarn machinery, such as: (1) Pickers, (2) Cards, (3) Combs, (4) and all heavy machinery, a heavy engine oil should be used [280 to 340 Vis. at 100° Fahr. (P. B.)] [350 to 500 Vis. at 100° Fahr. (A. B.)].

For *intermediate machinery,* such as: Flyer frames, including Slubbers, Intermediate, Roving, a medium viscosity engine oil should be used [175 to 200 Vis. at 100° Fahr. (P. B.)] [275 to 375 Vis. at 100° Fahr. (A. B.)].

WOOL SPINNING

The drawn and twisted wool, from the machines above described, is next brought to the spinning frames. Here the wool is given a final twist and draw.

These frames consist of rolls, which feed the wool to highly rotating

spindles carried on a carriage, in such a way that the yarn is drawn and twisted.

The revolutions of the rolls and the speeds of the spindles determine the weight of the yarns.

SPINDLES

The spindle has been developed to a high degree of perfection. A well-known authority states that there are over 500 patents covering improvements on it.

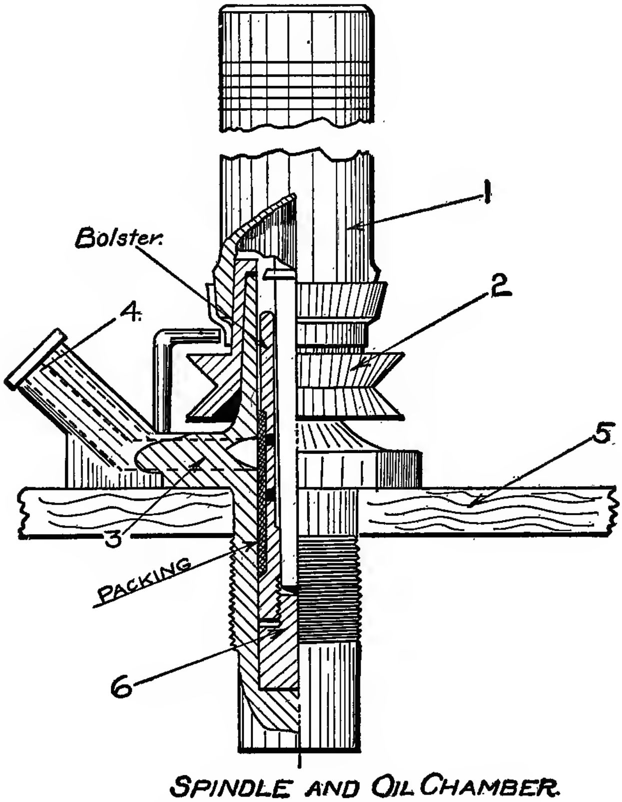


FIG. 96.—Sectional view of a Spindle.

Spindle speeds usually average between 8000 and 12,000 R. P. M. The spindles support bobbins, on which the yarn is wound.

The size, or capacity, of a textile mill is usually given as the number of spindles it has in operation.

Fig. 96 shows an elevation of a well-known type of spindle and a sectional view of the same. Referring to the figure:—

(1) Spindle blade.
(2) Whorl.
(3) Oil cup.
(4) Oil-filling tube.
(5) Spindle rail, on which the cup is mounted.

The end of the spindle is blunt and bears on the plug or "bolster," (6). (In some types, a step bearing is provided.)

It has been stated by several authorities that a spindle under average conditions and revolving at 7000 R. P. M. consumes about 0.00750 H. P., and one revolving at 11,000 R. P. M. uses 0.01625 H. P.

The Lubrication of Spindles.—It is essential that spindles be lubricated with oils especially prepared for that purpose. These oils must be limpid and free-flowing. They must, however, possess sufficient viscosity to form a protective film of lubricant between the bolster and the spindle.

The oil should have a good evaporative test. When heated for 12 hours at a temperature of 150° Fahr., the oil should not lose more than 4 per cent. (See "Oxidization and Spontaneous Combustion," Index.)

The flash test of any oil used in the lubrication of a textile mill should never be below 325° Fahr.

Excessive viscosity of spindle oils will tend to greatly increase the friction load of the mill.

The following viscosities are suggested as a guide for the selection of spindle oils for various purposes:—

For bath or Rabbeth spindles, doublers, etc. [95 to 100 Vis. at 100° Fahr. (P. B.)] [100 to 110° Vis. at 100° Fahr. (A. B.)].

For mule spindles, cup spindles, open bolster, sawyer type spindles, etc. [140 to 150 Vis. at 100° Fahr. (P. B.)] [170 to 180 Vis. at 100° Fahr. (A. B.)].

For the general lubrication of ring spinning frames, cap spinning frames, etc. [140 to 150 Vis. at 100° Fahr. (P. B.)] [170 to 180 Vis. at 100° Fahr. (A. B.)].

For the lubrication of the front and top rolls of cap spinning frames and for mule frames [270 to 280 Vis. at 100° Fahr. (P. B.)] [400 to 425 Vis. at 100° Fahr. (A. B.)].

Notes.—A good rule is to oil all spindles on the frames at noon hour. There are several makes of bolsters. The old type required that the spindle be lifted from the bolster and the oil poured into it. When the spindle is replaced in this type, the excess oil is squeezed out and usually drips on the frame and then to the floor. In other makes of bolsters, the oil is poured through a tube into an oil cup, making possible the oiling of a great number of frames per day.

" Rail rods " should be oiled every week, when the rails are washed. Oil on the rail rods lasts a long time and they require only a small amount.

The other parts should be oiled at least twice a day.

In mills of any size, amazing results will be produced, if a special man, or boy, is detailed to attend to the oiling and wiping of the many bearings, with some degree of regularity. It will pay large returns to any mill owner if he will spend some of his time in investigating the lubricating conditions in his mill.

Bands on whorls should have a tension of about two pounds. If these bands are too loose, slipping will occur, and if too tight, they will cause a considerable increase in friction. These bands are usually made of twisted " roving," and they are passed around a cylinder, five or six inches in diameter, which runs the length of the frame.

The temperature of the spindle bases will exceed that of the room temperature by about 15° Fahr., normally. A reduction of the temperature of the bases is an indication that the friction of the frame has been reduced.

WEAVING OPERATIONS

The weaving operation is described briefly as follows:—

The yarn is placed on a spool, by means of a " spooler." This is called " warp yarn."

A " warp " is made by combining a number of threads, or " ends," as they are called, in a carefully planned order of definite lengths, and winding these ends onto a cylinder, which is called a " warp beam."

The spools are placed in definite positions on a frame called a " creel."

The warp is usually "sized" by passing it through a starch mixture.

Power Looms.—The principal parts of power looms are as follows: (1) Frame, (2) Warp Beam, (3) Cloth Roll, (4) Heddles and their mountings, (5) the Reed.

Warp Beam.—The warp beam is usually a wooden cylinder, which is mounted at the back of the loom, and on this the warp has been wound, as stated above.

The "warp threads" are extended in parallel order to the "cloth roll," which is mounted at the front of the loom. Each thread or group of threads is passed through an opening, or "eye," of the "heddle."

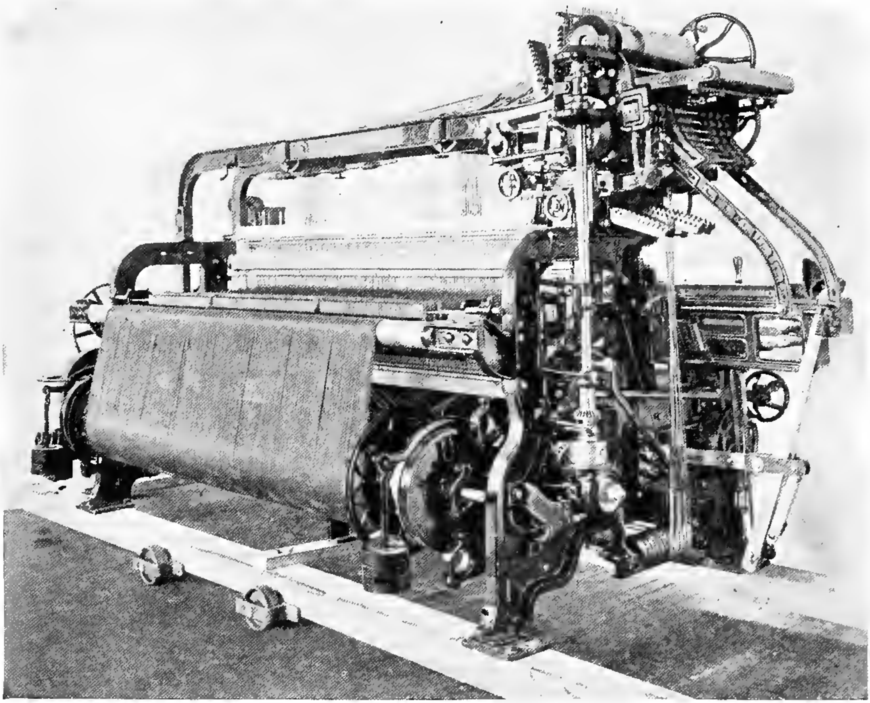


FIG. 97.—Back view of Automatic Heavy Worsted Loom.

The threads are divided by the heddles and each division is raised or lowered by the movement of the heddles. Each time the "harness" is pulled up or down, the two or more divisions of the warp threads are separated, so that an opening, called the "shed," is made between the upper and lower warp threads. Through this "shed" the "shuttle" is thrown, and the "filling thread," which is wound on a "bobbin," is carried through with it.

As soon as the filling thread is interlocked with the warp threads, it is pressed close by the "reed," to make the cloth firm and tight.

Weaves.—(*a*) Homespun or plain weaving has a warp and filling thread running at right angles to each other.

(*b*) Twill has the filling pieces under different warps, and is obtained by moving the warp to the right or the left.

Figs. 97, 98 and 99 show two back views, taken from opposite ends, and one front view, of the well-known Automatic Heavy Worsted Loom

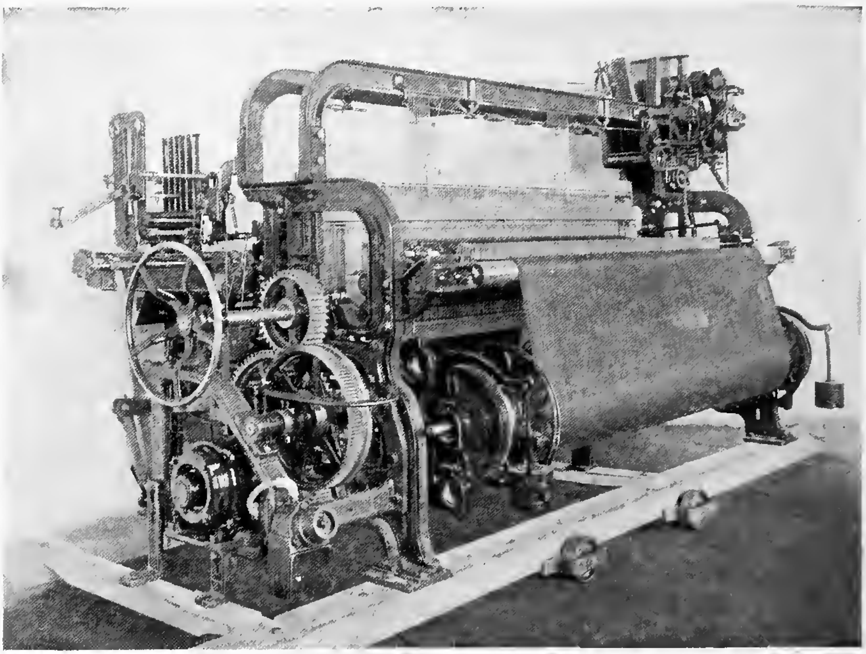


FIG. 98.—Back view of Automatic Heavy Worsted Loom.

made by The Crompton-Knowles Loom Works, of Worcester, Mass., and is shown through the courtesy of that firm.

Lubrication.—These cuts clearly show the type of lubrication met with in this class of machinery. A medium-bodied engine oil is suggested for use on these machines, as follows: For worsted, cotton, or woollen looms, plain and fancy types [260 to 300 Vis. at 100° Fahr. (P. B.)] [350 to 450 Vis. at 100° Fahr. (A. B.)]. For use on gears, a cup grease of No. 3 body is recommended.

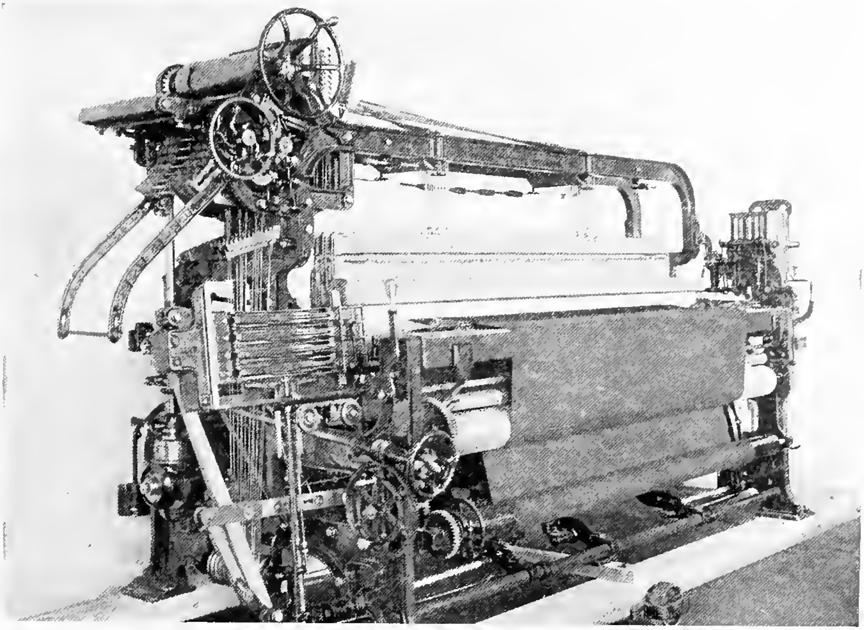


Fig. 99.—Front view of Automatic Heavy Worsted Loom.

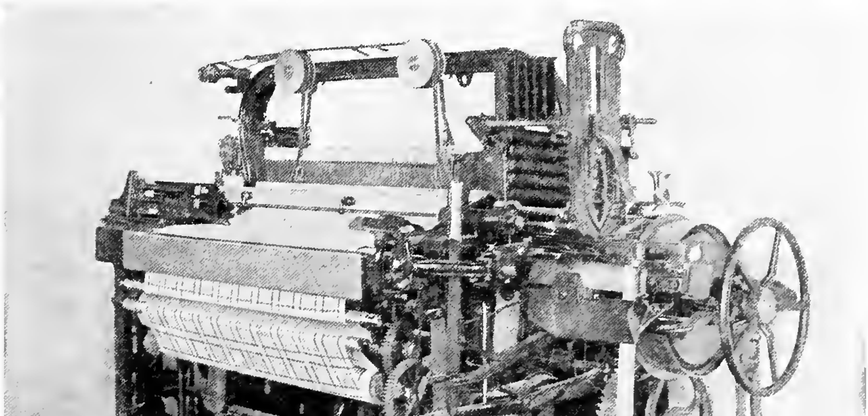


Fig. 100.—Front view of Automatic Gingham Loom.

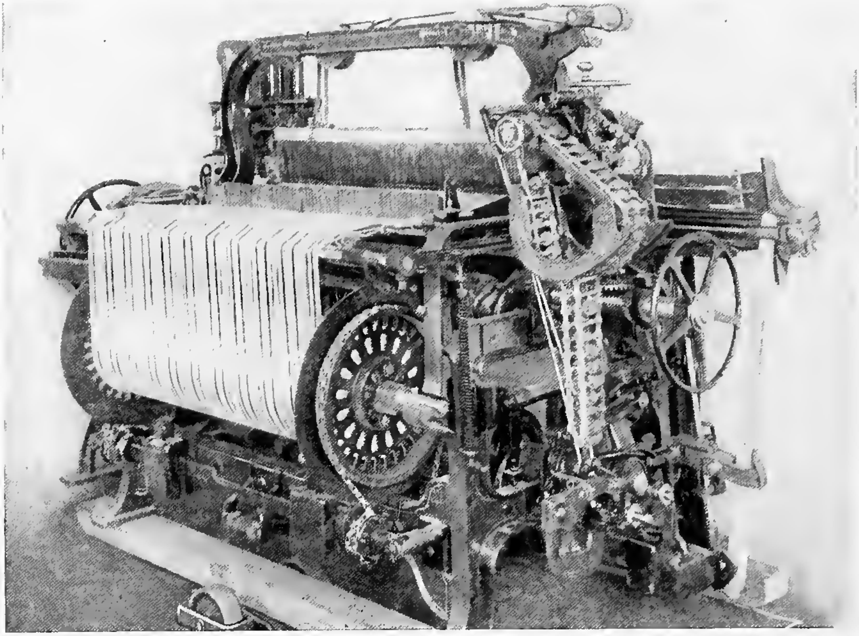


FIG. 101.—Back view of Automatic Gingham Loom.

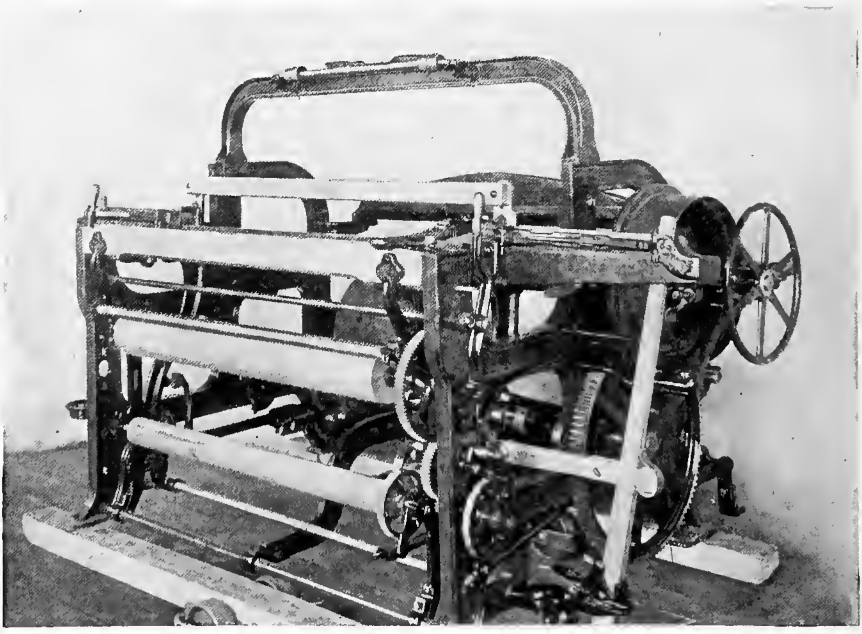


FIG. 102.—Front view of a Light Duck Loom.

Figs. 100 and 101 show front and back views of an Automatic Gingham Loom, shown through the courtesy of The Crompton-Knowles Loom Works. Figs. 102 and 103 show front and back views of a special Light Duck Loom. This loom is also shown through the courtesy of The Crompton & Knowles Company.

The same oils and greases are recommended for use on these machines as are suggested for the worsted looms, etc., above.

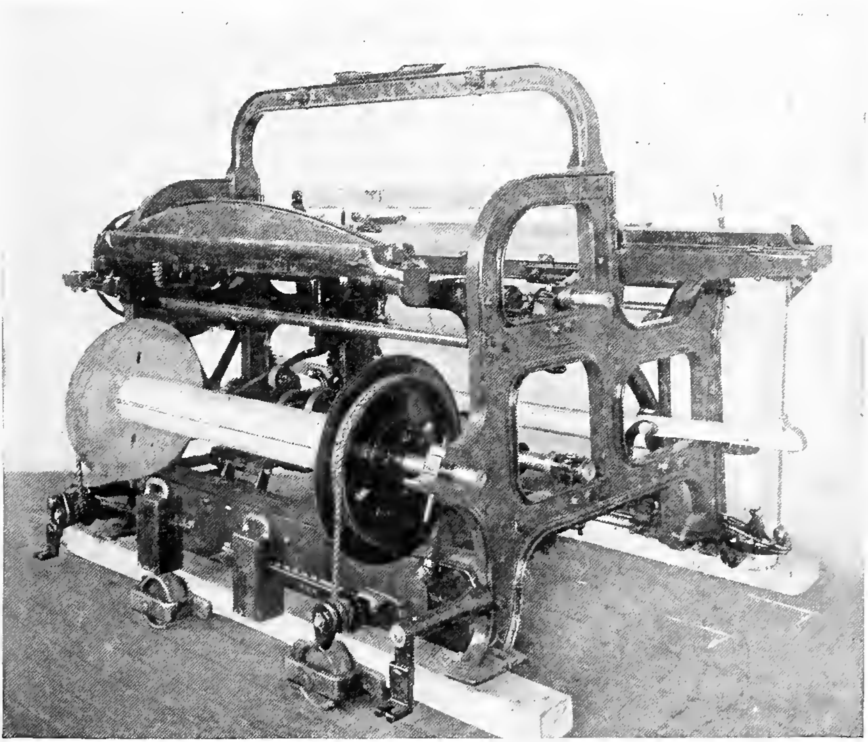


Fig. 103.—Back view of a Light Duck Loom.

KNITTING AND KNITTING MACHINES

Knitting.—This process consists in forming fabrics by looping a single thread.

"Circular knitters" produce a cylindrical web of various degrees of fineness. The circular fabric must then be cut and joined to make a garment.

"Plain knitters" produce plain fabrics only, and "ribbed machines" make "ribbed fabrics." Therefore half hose, or underwear with cuffs, must have the ribbed parts knitted on one machine, and then the piece is transferred to a plain machine to be finished.

Hosiery.—There are several kinds, called cut goods, seamless, or full-fashioned.

"Cut goods" are made of round webbing, knitted on a circular machine. The web looks like a long roll. First it is cut off to stocking length, and it is then shaped, by cutting out and sewing up, or it may be shrunk. It is next slit for the insertion of the heel, and the heel is sewn in. The toe is now put in. The hose is then scoured, dyed, and shaped.

"Seamless hose" is made on the same machine. The toe piece is left to be joined by the "looper." The ankle is made the same size as the calf, and to remedy this, the hose is steamed and shaped on boards.

"Full-fashioned hosiery" is produced by means of expensive machines, which automatically drop the requisite number of stitches, at the ankle, to shape the leg. The toe is produced in the same way, also the shaping of the heel and "gusset."

Full-fashioned hosiery is made on several machines. One makes the leg to the foot, one knits the foot, next the "looper" stitches the heel and toe together. The hose is then dyed, "boarded," stitched and dried, and finally heated and pressed.

Full-fashioned Underwear.—This class of underwear is knit flat and then sewed together.

Lubrication of Knitting Mills.—For this type of machinery, a spindle oil of about 100 to 110 Vis. at 100° Fahr. (P. B.), and slightly higher in viscosity for an (A. B.) oil, will have the proper body to meet the mechanical conditions of the small running parts. For the general lubrication of circular knitters, a neutral, filtered engine oil of 140 to 150 Vis. at 100° Fahr. (P. B.) will fill the lubricating requirements.

For the lubrication of the needle motion plates of horizontal knitting machinery, a filtered cylinder oil of 130 to 140 Vis. at 212° Fahr. will give the best results.

Highly filtered oils, called stainless oils, are demanded by some mills, under the impression that they will not cause oil spots in the finished pieces. This belief is without foundation, however, as any petroleum oil will "spot" and cause trouble, when the piece is being dyed. Oil spots

prevent the dye taking uniformly. Some textile oils are compounded with lard oil to increase their saponification properties, with a view to aiding the removal spots by washing.

FIRE RISKS FROM OILS IN TEXTILE MILLS

The statements of several authorities regarding the spontaneous combustion of oils and oily waste may be summarized as follows:—

The fire risk from the spontaneous ignition of oily material is increased the more readily oxidizable the oil is.

Mineral oils, which do not oxidize,* do not heat, and are not as subject to spontaneous combustion as those oils which are readily oxidizable. It is generally stated that when a mineral oil is compounded with a sufficient quantity of fatty oil, it will prevent the possibility of spontaneous combustion arising from the mixture. Usually the more mineral oil of 350° Fahr., or more flash, that is in a compounded lubricant, the safer the oil is, as regards fire risk.

Insurance companies, however, consider that the fire risk in the textile mills is increased, when the compounded lubricating oil used contains a large percentage of petroleum oil and a small percentage of compound. This is due to the fact that when a fire is started, the lower flash test mineral oils assist the spread of the fire, more readily than the higher flash compound oils.

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* NOTE.—See Appendix for other facts regarding oxidization of mineral oil.

CHAPTER XXXII

TRANSFORMERS AND TRANSFORMER OILS

Transformers.—For a brief description of the working principles of the electric transformer, refer to the section on "Electrical Engineering."

Transformer Oils.—Transformer cases are provided with oil, surrounding the coils, because oil is a better conductor of heat than air, and the heat caused by the electrical energy lost in the transformer is therefore more quickly transferred to the casing and there dissipated to the air.

Transformer oil also aids in keeping the insulation soft and reduces the oxidation effect of the air.

Transformers are made with capacities as high as 14,000 kilovolt-ampères, and may contain as much as 11,000 gallons of oil.

It is believed that the maximum dielectric strength possible, to theoretically obtain, is about 70,000 volts.

Specifications for Transformer Oils.—The requirements of a satisfactory transformer oil are as follows:—

(*a*) It must show an absence of moisture.

(*b*) It must show a good dielectric strength.

(*c*) It must have a low viscosity, to facilitate the heat transfer from the core and winding, to the case.

(*d*) The oil must have a flash-point of two or three times the "temperature limit" of the transformer.

(*e*) The oil must be neutral in its reactions.

(*f*) There must be an absence of any adulteration, or of animal and vegetable oils.

(*g*) The oil must not contain any metallic salts.

A typical specification for a transformer oil would read as follows:—

(*a*) The oil must be a pure mineral oil, obtained by fractional distillation from petroleum, unmixed with any other substance and without any chemical treatment.

(*b*) The flash-point should not be less than 310° Fahr., and the fire-point must exceed 340° Fahr.

(*c*) The oil shall contain no moisture, acid, alkali, or sulphur.

(*d*) There shall not be more than 2 per cent. evaporation loss, when the oil is heated to 190° Fahr. for a period of 8 hours.

(*e*) When heated to a temperature of 450° Fahr. and held at that temperature for five minutes, there should be only a very slight darkening of the oil, and when heated to this temperature for thirty minutes, there should be no dark particles or flocculent precipitate liberated.

(*f*) It is desirable that the color be No. 2 standard or better.

Notes on Transformer Oils.—It has been stated by several engineers, that traces of water in transformer oils may be removed by the following method: "One pound of sodium is added to each 25 gallons of oil. Due to the high affinity of sodium for water, it acts very energetically with the evolution of hydrogen."

It was stated that the Niagara Company, by the above method, has obtained 20,000 volts with an oil which formerly had been reduced to only 3000 volts. The above method is merely included as being of interest, but no recommendation is made concerning its use.

Effect of the Moisture Content upon the Dielectric Strength of Oil.—Mr. W. E. Temple, a consulting electrical engineer with wide experience in the testing of transformers, has made the following recommendations to the author, concerning the effect of moisture and other conditions upon transformer oils*:—

"The decrease of dielectric strength of a transformer oil is very rapid with the increase of moisture content in the oil, particularly when passing from a 'dry oil' to a moisture content of approximately one part in ten thousand (1–10,000). A sample under careful test showed a reduction of about 60 per cent. in puncture point when tested, first, in as near a 'dry' condition as possible to obtain, and, secondly, with a moisture content of approximately 0.010 per cent. The same sample showed a puncture point of only 20 per cent. lower (in terms of its dry value) upon a moisture increase to 0.10 per cent."

For indoor conditions, Mr. Temple advises that he would design the oil-containing apparatus on the "dry" basis, but for outdoor work he would assume that a certain amount of moisture was present: the exact amount to be assumed, to depend upon the conditions under which the transformer was expected to be operated.

Laboratory tests for oils to be used for electrical purposes must copy

*Note.—See curve in Appendix showing the decrease in dielectric strength of transformer oil, with the increase of moisture content.

exactly the electrical and working conditions under which the oil is expected to work, in order that the tests may have any real value.

When filtering oil from a transformer tank, it is preferable to filter from one tank to another, so that the oil may receive more complete treatment than if drawn from the bottom of the tank and returned to the top of the same tank.

If much water is present in the oil, allow at least 24 to 48 hours for settling, before filtering.

Oil which has been damaged by overheating from a continuous overload may be treated and benefited in one of the driers and filters now on the market. The oil will, however, remain darker in color.

In large stations, which have a large amount of piping for the purpose of transferring the oils to and from the transformers, it will be worth while to frequently inspect the piping to ascertain that there is no moisture in the pipes.

Dust has a very bad effect upon the dielectric strength of oil, having about the same reducing effect as water.

The inside surfaces of transformer casings must be kept free from slime and other coatings, to facilitate the transfer of heat from the oil to the casing.

Large transformers are sometimes equipped with a circuiting system for cooling the oil, either with air or water. There is considerable risk attached to cooling with water due to the possibility of the oil absorbing moisture. (For description of oil coolers see Appendix.)

High temperatures in transformers, which will result from poor cooling, will cause the insulation of the windings to deteriorate.

CHAPTER XXXIII

STEAM TURBINES AND THEIR LUBRICATION

HORIZONTAL TURBINES

Westinghouse Steam Turbines.—The lubrication of this type of turbine is accomplished by a closed oiling system, through which the oil is circulated by means of a pump, which is usually gear-driven from the main shaft. In the older types of machines the pump was of the plunger type, and in the newer machines a rotary pump is used.

The bearings are flooded at low pressure. In the usual, average-sized machine, the oil is drained from the bearings and passed through a strainer into a settling tank. The oil is next passed through a cooler, which is of the counterbalanced type; that is, the oil enters at the opposite end from the cooling water, the water being passed through a number of coils and the oil flowing about them. Usually the oil reservoir, cooler, and piping are located below and about the machine, being covered by a corrugated steel floor plate to improve the neatness of the installation.

For those turbines in which the oil-relay governing system is supplied with oil from the lubricating system, a higher pressure is produced by the pumps. The oil for the circulating system is passed through a spring loaded, pressure-reducing valve and thence through the cooler. The small quantity of oil for operating the valve passes to a relay cylinder and then exhausts into the cooler. (See section on "Turbines.")

In turbines where the speeds are very high, the spindle tends to revolve on its gravity axis instead of on its mechanical axis. The method used to overcome this action in the Westinghouse turbine is worthy of notice and is described in another section of this book. (See Index.)

Lubricating Oil.—For the ordinary-sized Westinghouse turbine, the following oil as generally specified below will satisfy all conditions:—

(*a*) Viscosity .... 145 to 150 at 100° Fahr. (P. B.) *
(*b*) Gravity .... 30° to 31° B.
(*c*) Flash .... 390° to 400° Fahr.
(*d*) Filtered neutral oil.

* NOTE.—For the largest machines the viscosity should be increased to 180 to 190 at 100° Fahr. (P. B.).

Curtis Steam Turbines.—The oil for this type of turbine is supplied by a general circulating system. In the usual machine, a pump, gear driven from the main shaft, supplies the necessary oil pressure. In large machines, a separate steam-driven pump is provided. In certain cases, positive cooling is produced by water pipes imbedded in the bearing metal.

Lubrication.—The same oil is recommended for these turbines as is described under the Westinghouse turbine heading

DeLaval Steam Turbines.—The lubrication of this type of turbine should be considered from the standpoint of a high-speed engine. The bearings are usually supplied with oil by a multiple-feed oiler, pipes being carried directly from the main sight-feed box to the different bearings.

Lubrication.—A strictly neutral oil of 145 to 150 Vis. at 100° Fahr. (P. B.) will give satisfactory results in this turbine.

Notes.—The various mechanical features affecting the lubrication of the turbines referred to above are described in another section of this book. (See Index.)

In some cases, a central oiling system is employed instead of individual oiling systems, particularly where there are two or more turbines installed. One of the greatest advantages of a central system is that it can be designed to contain large quantities of oil in the settling tanks, thus allowing the oil to have a reasonably long rest between the periods of passing through the bearings.

It is always good practice to provide two oil pumps for all turbine oiling systems, so that one pump can be held in reserve in case the other gets out of order. Due to the high-bearing speeds, the oil supply must be plentiful to prevent overheating.

VERTICAL TURBINES

Vertical turbines are provided with step-bearing pumps to force the oil between the contact surfaces of the step bearings, against the "squeezing out" effect of the weight of the rotating element.

Step-bearing Pumps.—Step-bearing pumps should always be provided in duplicate to prevent the possibility of lack of oil pressure causing a shutdown. The pumps should always be equipped with a good governor.

When the plant contains several machines an accumulator should be provided. Auxiliaries, such as dry vacuum pumps, should be equipped

with grease cups. A medium grade of grease, such as No. 3 standard, is recommended for use in these cups.

Oil Filters.—The filters should be located so that they are readily accessible and easily cleaned. Good lubrication is impossible without efficient filtering, and only a frequently cleaned filter will produce good results.

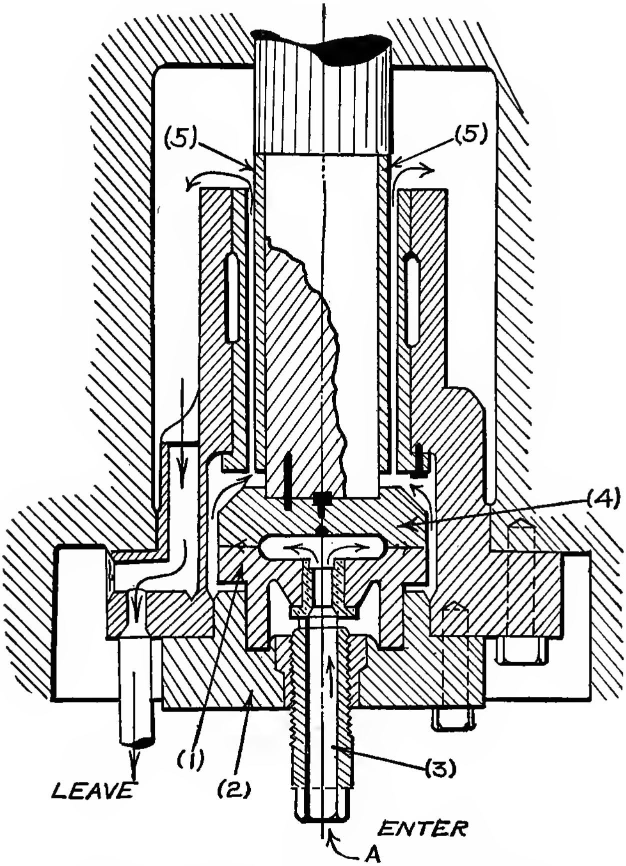

FIG. 104.—Sectional view of a vertical turbine step bearing.

Lubricating Systems.—Fig. 104 shows a typical vertical turbine step bearing and the method of lubricating it.

The upper and middle bearings of vertical turbines are of the regular sleeve type. The lower bearing is a step bearing, and the weight of the revolving element is supported by this bearing. The contact surfaces of

the step bearing must be separated by an oil film under pressure, and usually this pressure is about 600 pounds. The oil is forced between the upper and lower bearing blocks (4) and (1), through the pipe (*A*) (see Fig. 104).

The oil, after escaping under the block, passes upward through the steadying bearing and is drained back into the oil tank.

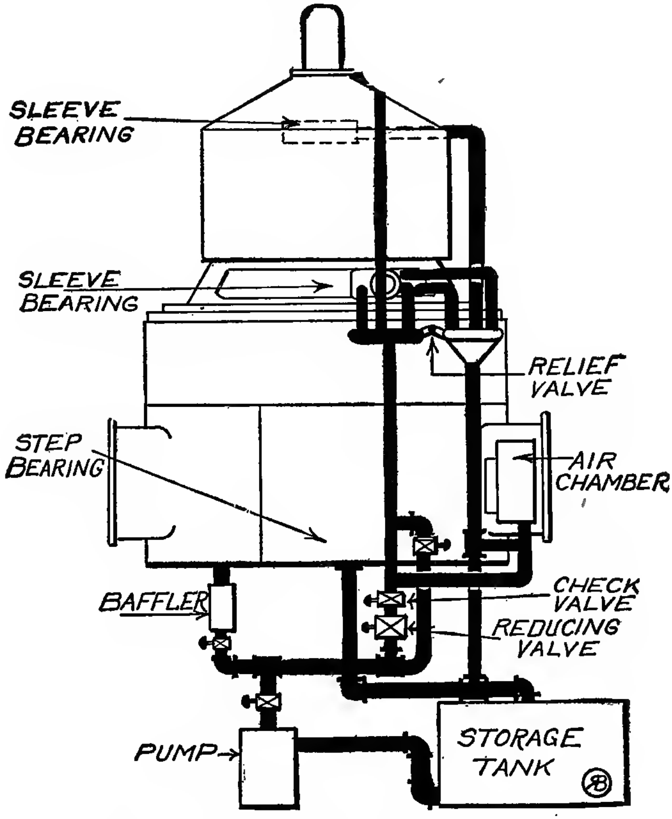

Fig. 105.—Lubricating system for vertical steam turbine.

The arrangements of the oiling systems used with these machines may be varied somewhat to meet individual conditions.

A typical lubricating system for this type of turbine is shown in Fig. 105. A tank of sufficient size to contain all of the oil and to permit of a good-sized surplus is fitted with suitable straining devices and a heating and cooling coil. This tank is located at a level low enough to

receive all of the oil by gravity, from all of the points of lubrication. A pump draws oil from the tank and delivers it at a pressure approximately 25 per cent. higher than is required to sustain the weight of the revolving element.

The vertical turbine is not being as generally used now as in the past, as most of the manufacturers are recommending horizontal turbines.

As is shown in Fig. 104, the bearing plate (1) is made of cast iron and is held by the frame (2). It is carried by a large screw (3), which passes through a steel nut, coming into contact with a steel block set in the bearing plate as shown. The step plate is shown at (4), which is keyed to the lower end of the shaft. Both plates are recessed, so that the contact surface is collar shaped. The guide bearing is shown at (5). The oil enters at (*A*), through the centre of the screw, and the path is shown by the arrows.

In operation, the contact surfaces of the steps should be separated by a film of lubricant.

Turbine Lubricating Oils.—Since the consumption of lubricating oil in a turbine is small, the loss of oil being practically due only to leakage and a small amount of evaporation and wear, the price paid for the oil should be a secondary consideration, the prime consideration being its suitability for the purpose.

A satisfactory turbine oil must possess the following requirements:—

(*a*) It must be absolutely non-emulsifying, and should be a filtered neutral oil. The best results are obtained with paraffine base oils, but turbine oils are made from asphalt base crudes that will give good service, provided they are carefully chosen. The asphalt base oils must be particularly examined to ascertain their freedom from acid and their non-emulsifying qualities.

(*b*) The viscosity of turbine oils should not be excessively high, even for the heaviest loads. The primary reason for this condition lies in the fact that it is not advisable to start with an abnormally high viscosity oil, in order to have the proper viscosity obtained at the working temperature, as this would be a particularly objectionable condition in a closed circuit system.

(*c*) There should be less than ¼ of 1 per cent. free acid in the oil.

(*d*) Turbine oil must be a strictly pure mineral oil.

(*e*) The flash-point should be 390° Fahr. or over.

Important Features.—It is very important to keep the lubricating system tanks and filters as free from moisture as possible. Constantly circulating the oil through the system tends to break it down and to destroy its non-emulsifying properties. The first indication that the oil has been broken down is usually a thick, slimy deposit in the strainers and filters. In time this deposit will become hardened.

Draining of Tanks.—Tanks should be frequently and systematically drained and all slime and foreign matter removed. Recent installations provide a reserve tank, so that the oil in one tank can be used while that in the other tank is settling or draining.

Exposure to the Air.—In some plants, warm oil coming from the bearings is allowed to drop from the exit pipe outlet, through the air for about a foot to a funnel, and then flow through the filters. This condition should never be permitted, because the warm oil will absorb dust very readily from the air and there will be constant trouble from deposits.

Steel Barrels.—If it is convenient, turbine oil should be delivered in steel barrels, to avoid any possibility of glue from a badly glued barrel, or moisture from exposure of the barrel to the weather, getting into the system.

Marine Turbine Installation.—On a large battleship the maximum temperature of the turbine oil after passing through the bearings was 105° Fahr. under normal conditions. The maximum reduction in temperature by a well-known make of film cooler was 25° Fahr. The specific heat of a typical turbine oil was found to be 0.468 at 100° Fahr.

Thermometers.—Thermometers are usually found at the outlets and inlets of turbine oiling systems. They should be located as near to the bearings as possible and the temperatures frequently noted.

Temperature of Oil.—The outlet temperatures of the oil leaving the bearings should reach a maximum very soon after starting the machine, and should continue at a fairly constant temperature thereafter.

Water in System.—Water mixed with oil in a system is hard to detect and difficult to remove. The only way that it can be removed is by settling and draining the oil, allowing at least 48 hours for this operation.

The Baffler.—The baffler is a device for restricting the flow of oil supplied by the pumps to the step and guide bearings of a vertical turbine.

This device consists of a square threaded plug in a suitable casing. The oil under pressure from the pump enters one end of the casing, and, due to the circular path it must travel about the threads of the plug, the flow is steadied and does not fluctuate as much with any change in pressure or load on the step bearing, as would otherwise occur.

A sectional view of a "Baffler" is shown in Fig. 106.

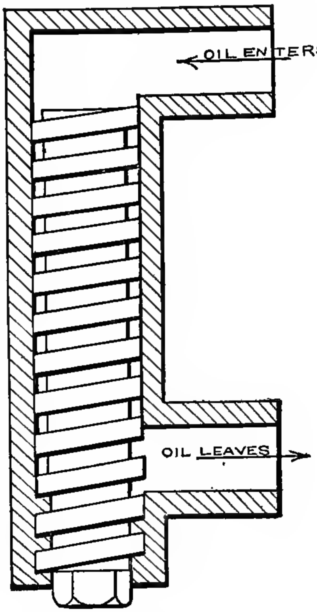

FIG. 106.—Baffler.

It has been found that there is a definite rate of flow of the lubricating oil between the blocks of the step bearing, which will give the best efficiency for various speeds and loads. By means of the baffler or governor, the flow of oil can be definitely adjusted and it is possible to maintain it practically constant.

The baffling effect may be lessened or increased by screwing the plug in or out of the casing, thus increasing or decreasing the length of the travel of the oil.

This device is also useful in cases where there are several machines having their oil supplies tapped into the same supply main, and equipped with a common pump. The baffler of each machine independently governs the flow to the step bearing of that machine, depending upon its own independent requirements and load.

CHAPTER XXXIV

WATER-WHEEL GENERATORS

THE utilization and development of water-power for the production of electrical energy has become very general throughout the United States.

There are two types of water-wheel generators, namely: Horizontal and Vertical.

A typical Vertical water-wheel generator as manufactured by The

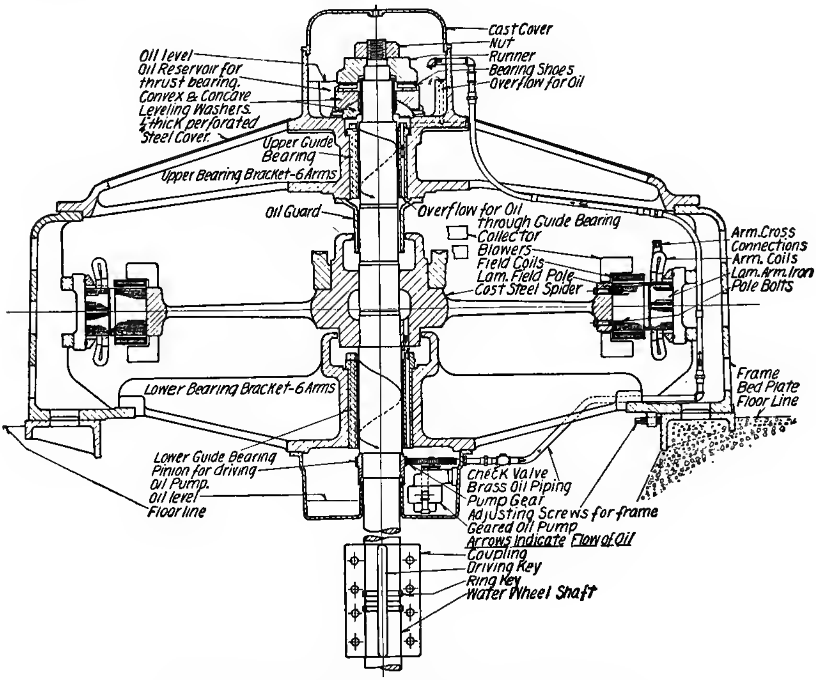

FIG. 107.—Cross-section of vertical water-wheel generator.

Westinghouse Electric and Manufacturing Company is shown in cross-section in Fig. 107.

The oiling system is plainly indicated, and the path of the oil travel is shown by arrows.

A good-bodied, filtered, neutral engine oil will give the best results in this type of machine. The oil must be *strictly neutral* and must possess

no emulsifying properties. It must be free from any adulteration. The viscosity of the oil should be [180 to 200 Vis. at 100° Fahr. (P. B.)] or a non-emulsifying oil of [210–220 Vis. at 100° Fahr. (A. B.)].

The pump for supplying the necessary circulation of oil is geared to the main shaft. A check valve is coupled in the feed line to keep it full and prevent the oil running back, which would require the pump to fill the line, before oil would be supplied to the upper bearing, when restarting the machine after it has been shut down.

CHAPTER XXXV

WIRE DRAWING AND ITS LUBRICATION

Wire Drawing.—Wire drawing is the process of reducing the cross-section of a metal bar, by drawing it through a tapering hole, whereby the metal is compressed and elongated.

The purpose of wire drawing may be to produce a smoothly finished product of more accurate size than can be obtained by rolling.

Fig. 108 shows a cross-section of wire drawing dies, the section being taken through one of the holes. For high carbon wire the die shown at *A* would be used, and for copper wire the die *B* is used. The large tapering portion *N* is used as a receptacle into which the rod carries the lubricating material, which is caught between the wedge-shaped sides of

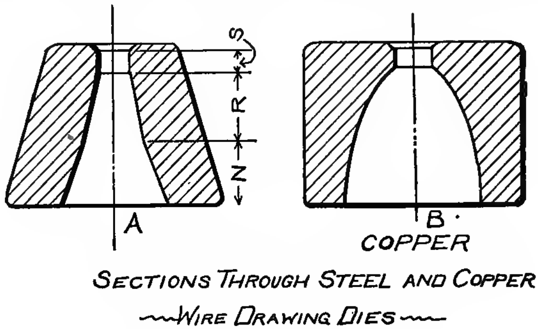

FIG. 108.—Cross-section of wire drawing dies.

the die, and carried along into the real working section at *R*. When passing through *R*, the real compression and metal flow occurs. The neck *S* merely serves to take up the wear on the die and becomes shorter in length, as the life of the die deteriorates.

Dies for high carbon wire have long working sections, as is shown at *R*, in die *A*, while copper wire drawing dies are shaped as is shown by die *B*.

Process of Wire Drawing.—The "rod bundle" is thrown on the "wire drawing bench" and given a tapering point. This point is entered into the die, which is held in a metal box. Lubricating grease, or powdered soap, fills the box, and as the rod passes through the die box, the

lubricating medium is carried into the hole and interposes a protecting film between the wire and the die. This prevents metallic contact, which would quickly ruin the wire and the die.

After the "tongs" have pulled through sufficient of the wire, its end is attached to the "drum," or "block," which is revolved and the "drawing" operation starts.

The "drum spindles" are driven by bevel gears and several block units are mounted on a frame or "wire bench."

Lime Coat.—An important factor in the lubrication of drawing iron wire is the lime coat. When the rods first come to the wire mill, they are covered with scale. This scale must be removed, as its hard surface would destroy the die hole.

To accomplish the removal of the scale, the rods are immersed in hot, diluted sulphuric acid, which dissolves and loosens it. A stream of water is then run on the rod bundles and the loosened scale is washed off. The rods are next immersed in a hot lime-water vat and a thin lime coating adheres to them. This coating is believed by wire manufacturers to have great value in aiding the lubrication of the metal as it is drawn through the dies. It is not known whether the lime combines with the grease to aid it in lubrication, or whether the roughened surfaces merely aid in carrying an increased quantity of the lubricant into the die. The lime-coated rods are baked before being taken to the wire benches.

Sull.—If water is sprayed on the rods after cleaning in the acid, a soft, slippery coating of iron oxide is formed upon their surfaces. This coating is covered by the lime coating and acts as an additional aid to the lubrication of the rod during the drawing operation.

Redrawing.—Wire may be subjected to several drawings through "reducing dies" before the final resulting size is obtained.

Lubrication.—A typical *"drawing oil"* would have these general tests:

(*a*) 24 to 25 Gravity.
(*b*) 400 to 420 Open Flash.
(*c*) 170 to 180 Vis. at 100° Fahr.
(*d*) 30 to 40 Cloud.
(*e*) 50 per cent. Cotton-seed Oil.

"*Wire-drawing grease*" is usually made in two consistencies, No. 2 and No. 3, and is a good quality petroleum, lime grease.

In dry wire drawing, which may be used for sizes down to No. 18, tallow or soapstone is used as a lubricant.

"Petroleum Grease" is sometimes used for this purpose.

PART V

CHAPTER XXXVI

THE COST OF LUBRICATION

THE "*cost of lubrication*" is closely connected with the "*cost of power*" and operation of all power plants and mills. In the average plant large savings may be effected in the cost of power by expending thought and care in the selection, purchase, and application of the proper lubricants to the prime movers, transmission shafting, and individual machines.

In factories and mills using individual motor drives on the various units, the necessity for the reduction of the friction loads of the transmission shafting is, of course, eliminated. There are, however, great possibilities for reducing the friction loss in the prime mover and the electric generator, with a resulting reduction in the cost per kilowatt for the power supplied to the various units. Reductions in the friction loads, of the various motor-driven units, may be easily detected by the use of instruments for measuring the power input, to the machines.

OUTLINE OF METHOD TO BE USED FOR THE SELECTION AND PURCHASING LUBRICANTS

The steps necessary to secure the most efficient and economical lubrication of a plant may be outlined as follows:—

1. Study the mechanical and physical conditions which directly or indirectly affect the lubrication of the plant.

2. Select a lubricant, or lubricants, that will satisfy the determined mechanical and physical conditions, *economically* and *efficiently*. This selection may be accomplished as follows:—

(*a*) By inviting several well-known and reputable oil companies to run individual and competitive tests on a typical unit, in coöperation with the chief engineer of the plant, with the view of obtaining the minimum cost of lubrication and for the purpose of awarding the lubricating contract for a period of at least two years, to the company showing the best economy.

(*b*) Another method is to run efficiency tests upon various units in the plant, or on the plant as a whole, using various oils which appear to fulfil the physical and mechanical requirements. The most efficient lubricants for the various machines may then be selected. These lubricants can be given to a chemist, experienced in the testing of oils, and the physical characteristics of the oils determined. Specifications may then be written and submitted to the oil companies for bids, covering the requirements of lubricants for a period of a year. (See "Advantages and Disadvantages of Oil Specifications," Index.)

3. Check up all deliveries of the lubricants as to uniformity and correct gallonage. (See Index for "Method of Checking Deliveries by Weight.")

No plant is so small that it can afford to give any less consideration to checking the delivery of the proper and full amounts of oil gallonage as paid for, than is given to noting whether the employees report on time for work, or only work half a day and receive pay for a full day.

4. Apply the lubricants efficiently by means of suitable distributing appliances, to the exact surfaces requiring lubrication.

5. Provide suitable arrangements for collecting and recovering the used oil, if possible, and settle and filter it for re-use.

A properly designed lubricating system will soon pay for itself, by reducing the amounts of oil used and by giving more uniform and effective lubrication.

6. Particularly in large plants, and generally in the average-sized mill, one man should be put in charge of the oil and grease stores. When lubricants are issued, a careful record should be kept, showing who received them and what use was made of them. Careless and wasteful employees and worn-out and efficient machinery may thus be easily detected. (See Index for " Oil-house Methods.)

THE COST OF LUBRICATION

The cost of lubrication must include not only the actual cost of the lubricants, but also the cost of power necessary to overcome the friction load and the wear and tear on the machinery, which can be traced to faulty lubrication.

The "*cost of lubrication*" may therefore be reduced, by obtaining the results as summarized in the following outline:

1. *By reducing the frictional power losses in the prime mover:*—
   Frictional losses in a prime mover may be as high as 20 per cent. of the power supplied to it. In modern high-speed engines, this loss may be reduced to 3 or 4 per cent., and the older types of engines to 6 or 8 per cent., by efficient lubrication. (As pointed out in another section of this book, it costs the large producer of power about $15 per year per horse-power, and the small producer up to about ten times that amount.) The possibilities of effecting a saving are evident.
2. *By reducing the friction losses of the transmission shafting:*—
   Shafting losses often run as high as 60 per cent. of the power transmitted to it, averaging about 35 per cent. It is possible to reduce this loss to about 10 per cent. Often as high as 40 per cent. savings have been effected in the friction losses of transmission shafting by changing the grade of the lubricant. Of course, proper alignment, ring oilers, and properly adjusted belting play a most important part in shafting friction losses.
3. *By reducing the frictional losses in the individual machines:*—
   Practical tests on various machines show frictional losses, ranging from 10 to 50 per cent. of their full load power. In large mills particularly, even a small reduction in the frictional loss per machine will effect a large total saving in the plant.
4. *By decreasing the cost of repairs and depreciation:*—
   Repairs average from 5 to 25 per cent. of the total cost of power.
5. *Depreciation* of plant equipment is usually figured at the rate of 20 to 30 per cent. per year, of the cost of producing power. That is to say, at the end of ten years the average industrial machine must be renewed. If the wear and tear on the machine is decreased, it is evident that this large depreciation charge can be reduced, with a consequent reduction in the cost of power.

   There is, however, one part of the depreciation charge which cannot be decreased by any method. This is that depreciation which is due to the improvements that are constantly

being made in machinery, which compel the manufacturer to install new machinery to keep up to the highest types of improved machinery in his line.

6. Considered from the standpoint of ultimate economy, the actual cost of lubricating oils and greases necessary to produce good lubrication is insignificant, when compared with the large saving in power costs resulting from their use.

DEPRECIATION COST OF LUBRICATING OILS

Investigation of Lubricating Oils by Fractional Distillation.—With a view to investigating the properties of asphalt base oils and paraffine base oils with respect to the relations between viscosity, flash-point, specific gravity, and volatility of their component fractions, a comprehensive series of tests has been started by the Engineering Experiment Station of the United States Navy at Annapolis, Md.

The results of some of these tests were reported by Mr. J. G. O'Neill, a chemist at the station, in a recent issue of the *Journal of the American Society of Naval Engineers.* The author was also in touch with these tests to some extent, and a description of the partial results is given as follows:—

The purpose of the tests was to separate the mineral lubricating oils into their component light, intermediate, and heavy oils, and to investigate the properties of the various fractions. Great care was taken to prevent the decomposition of the component oils, and by reuniting the component parts the original oil could be generally obtained. The fractional distillation was carried out by the use of heat and superheated steam. The laboratory apparatus was carefully planned and gave accurate results.

The fractions were made as nearly equal in weight as possible, and there were usually four or five of these fractions.

The oils tested were straight mineral oils and may be listed as follows:—

1. Light Forced-feed Oil	Asphalt Base
2. Medium Forced-feed Oil	Paraffine Base
3. Medium Forced-feed Oil	Asphalt Base
4. Medium Forced-feed Oil	Asphalt Base
5. Medium Forced-feed Oil	Paraffine Base
6. Light Forced-feed Oil	Asphalt Base
7. Ice Machine Oil	Asphalt Base

The viscosities, flash-points, fire-points, and specific gravities of the original oils and their fractions were taken.

The original sample of oil taken for test was about 600 c.c., and this allowed five fractions of about 120 c.c. each.

The following table shows some of the results:—

Number of oil	Fraction	Per cent. total	Vis. Say. at 100° Fahr.	Flash, Fahr.	Baumé gravity	Fire-point
1	Original	———	199.0	312	19.4	364
	A	17.38	64.8	273	22.6	300
	B	22.32	108.5	328	20.5	362
	C	20.10	202.4	360	19.4	408
	D	22.78	428.5	408	18.6	458
	E	17.42	2,581	404	17.5	440
2	Original	———	205.0	395	27.8	455
	A	18.31	99.6	326	29.7	360
	B	18.38	128.0	390	29.0	414
	C	18.49	164.0	388	28.6	405
	D	19.64	250.3	388	27.1	412
	E	25.18	619.8	453	25.5	486
3	Original	———	275.0	354	20.0	392
	A	27.23	91.2	316	21.3	338
	B	24.17	190.0	372	20.5	398
	C	28.39	414.0	390	19.7	405
	D	20.21	2,358	404	18.5	446
4	Original	———	316.0	348	21 0	384
	A	24.39	98.1	305	23.0	328
	B	22.30	197.2	358	21.85	383
	C	24.81	445.0	392	21.0	430
	D	28.50	1,402	438	20.0	450
5	Original	———	255.0	410	24.8	436
	A	22.48	126.2	338	26.2	362
	B	22.27	179.2	407	25.5	435
	C	20.97	248.0	427	24.8	442
	D	34.28	603.0	444	23.2	468
6	Original	———	178.0	403	28.5	464
	A	21.95	108.0	350	29.4	390
	B	24.23	140.2	368	29.5	405
	C	22.83	185.0	374	29.0	405
	D	30.99	380.0	444	26.9	468

The investigation, according to Mr. O'Neill, indicates several very important facts. Instead of a lubricating oil being composed of several oils having practically the same viscosity, it is composed of a large number of oils having a wide range of viscosities, and the viscosity of the oil, as known to the trade, is an average viscosity of all the component viscosities.

An analysis of the preceding table shows the following results in tabulated form:—

Oil number	Percentage composition by weight			Base of oil, grade
	Viscosity below 140	Viscosity 140 to 500	Viscosity above 500	
	Per cent.	*Per cent.*	*Per cent.*	
1	38.5	38.5	23.0	Light, asphalt.
2	30.5	54.5	15.0	Medium, paraffine.
3	29.0	43.0	28.0	Medium, asphalt.
4	25.0	39.5	35.5	Medium, asphalt.
5	17.0	63.0	20.0	Medium, paraffine.
6	36.0	74.0	00.0	Light, paraffine.

The conclusions drawn by Mr. O'Neill are as follows:—

Light oils, having a viscosity below 140° Say., are not desirable for use in the lubrication of machinery, because they are exposed to conditions of heat, steam, and agitation which rapidly vaporize them.

Heavy oils, above 500° Say. Vis., are undesirable, because they are more liable to decomposition than are oils of lighter viscosity, and on decomposition produce tarry or carbon deposits.

When heavy oils and light oils are mixed and give a medium oil, the viscosity of this oil is subject to a more rapid change than is a medium oil composed of closer fractions.

The life of a lubricating oil in service can be estimated, and those oils containing the largest percentage of component parts having viscosities between 140° and 500° Say. will give longer service than will those oils that are low in these fractions.

It is to be noted that for the same viscosity, the asphalt base oils are more volatile than are the paraffine base oils.

The recommendation is made that mineral oils should be compounded from oils which have narrow limits of vaporization temperatures, and that the oils should have as near as possible the same viscosity and gravity.

COMPARISON OF ULTIMATE ECONOMY OF LUBRICATING OILS

It has been practically impossible in the past to accurately compare the oils made from asphalt and paraffine base crudes, with a view towards determining the actual amount of lubrication which is obtained per gallon from the oils, in the same class of service.

Undoubtedly a mechanical study of the actual component parts of the oils, recommended for the same purposes, but made from different crudes and having widely separated physical characteristics, can be developed

to such a point that it will be possible to buy lubrication with as much intelligence as is now possible in the purchase of steel or coal.

Viewing the subject from another standpoint, if ten tons of lubricating oil are bought and after a thousand hours' use, the oil has lost a tenth of its weight by vaporization, while with another oil this loss would only have been one-twentieth of its original weight, then it is not correct to compare these oils on the basis of their actual cost per gallon or friction-reducing qualities alone, but we must also take the *depreciation cost* of the oils into consideration.

It is therefore strongly recommended that the present physical tests and practical friction and operating tests be completed by a *depreciation test,* and that some standard method be laid down for conducting these tests.

CHAPTER XXXVII

SPECIFICATIONS

Advantages.—The advantages of buying lubricating and other petroleum oils under specifications may be outlined as follows:—

1. Bids may be obtained and compared from many oil companies on the same grade of oils, thus assuring by competitive bidding the lowest prices.

2. The claims and counter-claims of the various oil companies, as to the particular merits of their own brands of oils, are eliminated.

3. The purchasing and application of the oils is standardized.

Disadvantages.—The disadvantages of buying lubricating oils under specifications are outlined as follows:—

1. There are very few chemists, outside of those specializing in the oil industry, who are equipped with sufficient knowledge of the characteristics of the various grades of lubricating oils and greases to enable them to prepare fair and intelligent specifications.

2. The crude oil conditions are constantly changing, and therefore a specification calling for a certain viscosity and gravity this year, may allow competitive bidding from many oil companies, then, due to a falling off in the production of certain fields and the increased production in other fields, the specifications may quickly become obsolete and limit the number of competitors for the business in succeeding years.

The gravity and the other characteristics may call for an oil from a particular field in which the conditions have materially changed. The result is an increased price for the oil, or restricted bidding.

3. In preparing specifications, some particular oil must be used as a sample. Specifications written on tests from this sample limit the source of the crude from which the specification oil can be made. This may be desired, but such a condition prevents receiving the benefit of the constant improvements which are being made by the different lubricating oil manufacturers, in the oils made from the various crudes.

Writing Specifications.—If specifications are desired, they should not be too closely written. Their purpose should be to secure a satisfactory oil for fulfilling certain conditions, at the lowest competitive prices, and should not be written with the view of excluding oils made from crudes, other than that of the tested sample.

An exactly stated gravity, viscosity, and flash will pin all bidders to very narrow limits. Gravity is of no importance. Lubrication depends upon viscosity and its characteristic variations.

APPENDIX

CUTTING-TOOL LUBRICATION.

It has been generally taken for granted in the past, that the lubricant applied to tools during the cutting operation flowed between the edge of the cutting tool and the work. If the enormous pressure which is required at the cutting edge of the tool, and which often exceeds 100,000 pounds per square inch, is compared with the maximum pressure of even 1000 pounds per square inch, which a lubricant of as light a viscosity as that required for cutting-tool lubrication must have, it can be readily appreciated that the lubricant does not form a film between the tool edge and the work.

When metal is cut, there is a large amount of heat generated. This heat is produced by the slipping of the metal chip over the face of the tool, by the separation of the chip or cut from the metal body, and by the "crimping" of the "cut."

Cutting Cost.—The cost of cutting metal is affected by the efficient removal of the heat generated by the cutting operation, as follows:—

Analysis of Cost of Cutting Metal

(*a*) Cost of labor.

(1) Operation of the machine.

(2) Time required to change dull tools.

(3) Time required to redress the tool.

(*b*) Cost of power to drive.

(*c*) Cost of tool steel.

The Effect of Good Cutting Lubrication and Cooling

(*a*) The "power cost" is decreased, by the increased speed possible with *sharp tools.*

Sharp tools are only possible when the heat of cutting is removed at a sufficiently high rate, by the lubricant, to prevent the overheating and drawing of the temper of the high carbon steel used to make these tools.

(*b*) The "cost of labor" is reduced by the reduction in the cutting time possible with *sharp tools* as outlined above. It is also reduced by the longer life of the cutting edge due to the temper not having been drawn

by the excess heat carried away by the lubricant, and the less frequent redressings required by the tool.

(*c*) The "cost of tool steel" is reduced by the longer life of the tools due to the less frequent redressings required under the operating conditions made possible by good lubrication.

Production Speed.—Increases in the speed of production made possible by efficient cooling or "lubrication" have been found to exceed 35 per cent., and a fair average may be taken as 25 per cent.

The Value of Soluble Cutting Lubricants.—Of all liquids available for the "lubrication" or cooling of the cutting operation, water has the highest heat-absorbing qualities. It can also be readily flowed into contact with the heated surfaces, but, due to its low viscosity, will not form a satisfactory lubricating film for the sliding of the chip over the face or lip of the tool. The rusting properties of water make it unsuitable as a cutting lubricant when used alone.

Petroleum oil, cotton-seed oil, and lard oil have the required body to form the necessary film on the tool lip, and, while their specific heats or heat-absorbing properties are only about half as high as water, they have the property of preventing rusting.

The usual soluble cutting oil is made of a combination of oils as outlined above, and is designed to permit its being mixed with varying amounts of water to form a stable cutting emulsion.

The amounts of water required, vary with the character of the work. For tough steel, a larger amount of water is used than for the more brittle metals, since the steel chips press against the face of the tool with greater force and for a longer distance.

INTERNAL-COMBUSTION ENGINES

Horse-power Formulas.—

$$\text{I. H. P. (Indicated Horse-power)} = \frac{\dfrac{L \times D}{T}}{33{,}000}$$

Where $L =$ Mean effective pressure during the working stroke.

$D =$ Length of the stroke in feet.

$T =$ The time of one impulse; or, the time of a complete cycle, that is, the time from one power stroke to the next power stroke.

$T = \frac{1}{N}$, where N is the number of power strokes per minute.

$N =$ For a 2-cycle engine the number of $R.P.M.$

$N =$ For a 4-cycle engine the number of $\frac{R.P.M.}{2}$

The above formula applies to the work done by one cylinder, and applies only to a single-acting engine; that is, one in which the propelling force acts only on one side of the piston. Practically all internal-combustion engines are single acting.

For a multiple-cylinder engine, the total power developed by the engine is the product of the power developed, by one cylinder as obtained by the formula above, multiplied by the number of cylinders. The power developed by any single-acting, single- or multiple-cylinder engine, may be obtained by determining the factors called for in the following formula and carrying out the calculations:—

$$\text{I. H. P. (for a single-acting engine)} = R \times \frac{P \times L \times A \times N}{33{,}000}$$

Where R = Number of cylinders.

N = Number of power impulses or explosions per minute.

P = Mean effective pressure in pounds per square inch, obtained by taking indicator diagrams and obtaining their mean height, to scale.

L = Length of the stroke in feet.

A = Area of the piston in square inches.

For 2-cycle engines, N equals the number of revolutions made per minute; and for 4-cycle engines, N equals the number of revolutions made per minute divided by two.

Horse-power Calculations.—For purposes of illustration the following typical example is worked out from actual figures:—

(*a*) Engine has 6 cylinders.

(*b*) Makes 1800 R. P. M.

(*c*) The mean effective pressure obtained by the indicator is 73 pounds per square inch.

(*d*) Stroke is 5¼ inches.

(*e*) Diameter of cylinder, or bore, is 3¼ inches.

(*f*) Four-cycle engine.

According to the formula:—

$$I.\,H.\,P. = R \times \frac{P \times L \times A \times N}{33{,}000}$$

$$= 6 \times \frac{73 \times \frac{5.25}{12} \times \frac{3.14 \times 3.25^2}{4} \times \frac{1800}{2}}{33{,}000}$$

$$= 6 \times \frac{73 \times .438 \times 8.27 \times 900}{33{,}000}$$

$$= 43.3\ H.\,P.$$

Society of Automobile Engineers' Horse-power Formula.—This formula is known as the S. A. E. formula and is an arbitrary formula, which will give a fair degree of accuracy, only when the speed of the engine is about 750 R. P. M.

The S. A. E. formula is as follows:–

$$S. A. E. (H. P.) = \frac{D^2 \times R}{2.5}$$

Where $D =$ Diameter of the cylinder bore.
$R =$ Number of cylinders.

OXIDATION OF AUTOMOBILE CYLINDER OILS

Data by Bureau of Standards.—In a recent paper, by Mr. C. E. Waters, Associate Chemist of the Bureau of Standards, Washington, D. C., on the subject of "Data on the Oxidation of Automobile Cylinder Oils," the following conclusions were stated:—

"The so-called 'carbonization' of automobile cylinder oils is due only to a very limited extent, if at all, to 'cracking,' but is caused by oxidation and subsequent polymerization."

"When an oil is carbonized in the laboratory, a brown coating is formed on the walls of the flask, which is usually called 'varnish,' and from the large mass of data obtained, the statement is verified, that there is no regularity in the amount of the varnish formed, and no connection between this and the amount of precipitate thrown down by petroleum ether."

"It is shown that the carbonization value of an oil is independent of the flash and fire-points and of the evaporation loss on heating."

"It was found that the greater the carbonization value of an oil at first, the more rapidly did it increase as the temperature was raised or the time of heating was extended."

"An oil which has a low carbonization value when heated to 250°, for two or three hours, and an oil showing a higher value under the same conditions, will be farther apart as the conditions become more severe."

"Mr. Waters suggests that it is unnecessary to heat oils in carbonization tests for as long a time as is usually prescribed, and recommends that the tests run only for two and one-half hours."

DIELECTRIC STRENGTH OF OIL AND THE EFFECT OF WATER

The curve shown in Fig. 109 was obtained by the General Electric Company to demonstrate the importance of using a suitable apparatus for drying transformer oils.

The curve particularly shows the large drop in dielectric strength that results from the presence of a very small amount of moisture.

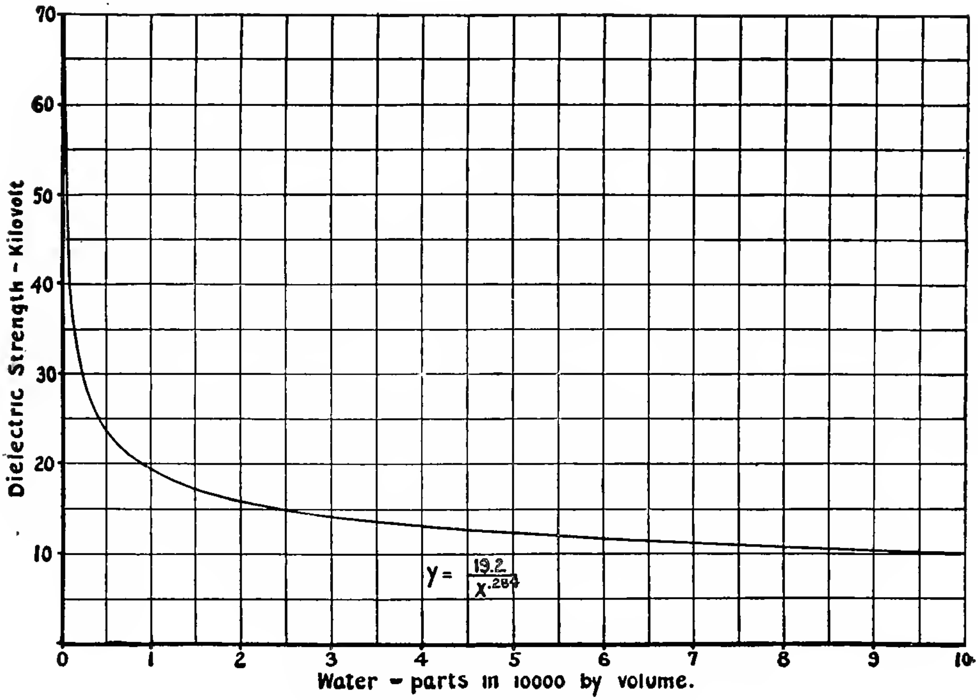

FIG. 109.—Curve showing the effect of water on the dielectric strength of oil.

OIL SWITCHES

The duties of oil switches are very important, and they may be called upon to operate under conditions that are much more severe than are met with in other high-voltage electrical apparatus. Great losses may follow the failure of oil switches to operate, and for this reason, their construction and the oil supplied to them, must be carefully considered.

Fig. 110 shows a Triple-Pole, 15,000-Volt, 2000-Ampère oil break switch made by the General Electric Company. The oil vessels for a switch such as this one, are 8 inches in diameter and hold 12 gallons of oil.

Fig 111 shows a section of an oil vessel and the oil baffles that are placed in it, to prevent the throwing of the oil, when the switch is opened. One of these baffles is used in each oil vessel of the switch. This switch is made by the General Electric Company, and a description of its operation is as follows: When the electric circuit is opened by pulling the switch, a movement is imparted to the oil, due to the expansion of the gases formed by the arc. The baffle checks this oil movement, in such a manner that the gases are allowed to separate from the oil and to escape from the oil vessel, through a vent in the top. The oil is forced back into the area of the breaking arc and shortens the time of breaking the arc. The baffle does away with the tendency of the oil to dash from the top of the oil vessel.

Oil for use in the oil switches must possess a high resistance to carbonization and must also have a good flashing-point. It should have a fairly low viscosity to permit of its quick flow towards the arc. The oil must be free from moisture, acid, alkali, or sulphur.

STANDARD SPECIFICATIONS FOR WASTE

Wool Waste.—This waste shall contain no other fibre than wool. It must be well machined and free from moisture, sweepings, flyings, and dirt.

Wool waste must be all-wool carpet yarn, and the threads must not be less than three inches long. The waste must contain at least 80 per cent. of new wool.

Colored Cotton Waste.—This waste shall contain no other fibre than cotton. It must be well machined, free from moisture, sweepings, flyings, and dirt.

This waste shall be composed of a mixture of colored and white cotton threads in equal parts. The threads shall not be less than three inches in length.

No material shall be used in the manufacture of this waste, which is not new, or which shows evidence of having been soiled, washed, and cleaned.

White Cotton Waste.—This waste shall contain no other fibre than cotton. It must be well machined, free from moisture, sweepings, and dirt.

Only new white cotton threads may be used, and their length must

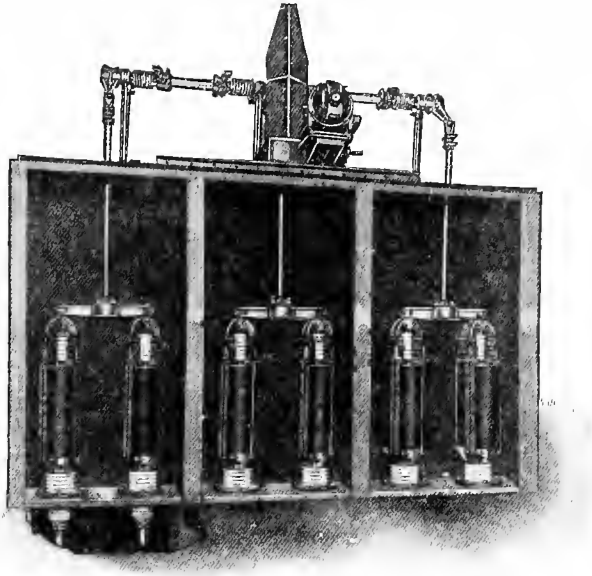

FIG. 110.—Triple-Pole, Single-Throw, 15,000 Volt, 2000-Ampère Oil-Break Switch. (Made by the General Electric Company.)

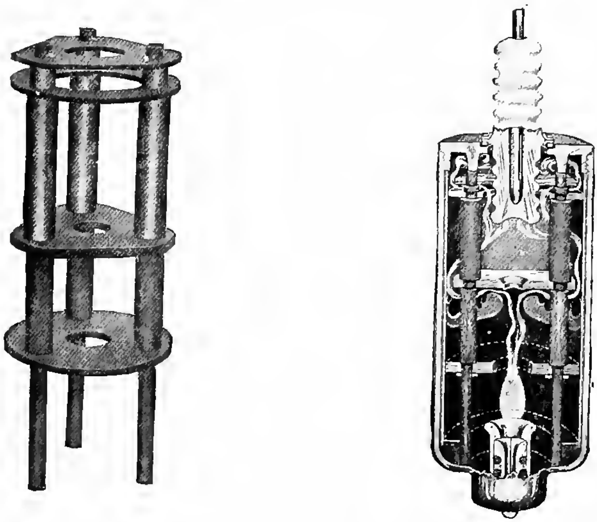

FIG. 111.—Oil baffle and section of oil vessel of the oil switch, shown in Fig. 110. (Made by the General Electric Company.)

be at least three inches. No cotton that has been soiled and washed may be used.

The gross weight will be paid for subject to the following provisions: The weight of the wrappings and hoops not to exceed 6 per cent. of the gross weight. The moisture not to exceed 3 per cent. of the gross weight. Any excess of the above weights up to 3 per cent. will be deducted from the payments, at the same price per pound as the purchase price of the waste.

If the moisture exceeds 6 per cent. the waste will not be accepted.

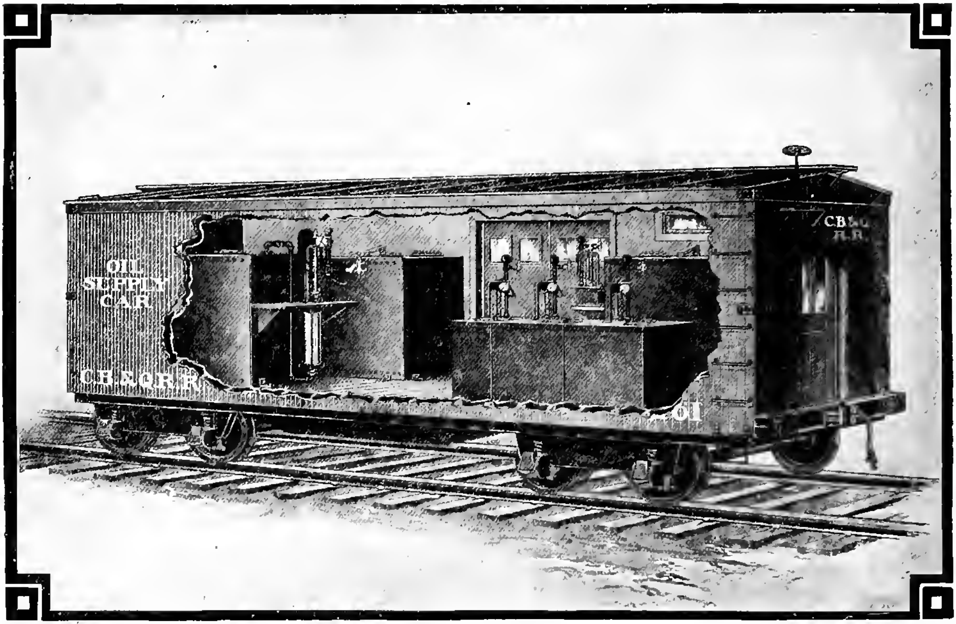

FIG. 112—Railroad Oil Supply Car.

THE STORAGE OF RAILROAD OILS

Car Storage.—Fig. 112 shows a modern equipped oil car for supplying oil at various parts of the system of a large railroad.

This car is equipped with tanks and measuring pumps and placed in charge of an efficient, careful man, who keeps records of oils issued and oils on hand, similar to those records kept by the main oil-house.

The car was designed by S. F. Bowser & Co. for the Chicago, Burlington & Quincy Railroad.

GREASE RETARDERS

Methods of Lubricating Large, Open Bearings.—For the lubrication of large, slow-moving bearings, that are equipped with open grease wells in the bearing cap, or, are merely furnished with a light bearing cover instead of a bearing cap, it is customary to apply the lubricant required, by one of the following described methods:—

(*a*) By fixing a piece of oil-soaked felt in contact with the exposed upper surface of the journal, as is shown in Fig. 47.

(*b*) By placing a stiff, heavy grease in the well, in direct contact with the upper surface of the journal.

(*c*) By filling the well with waste, which is oil soaked, and then feeding oil onto the waste as needed.

(*d*) By spreading grease over the upper surface of the journal by means of a "retarder." Ordinary, medium melting-point grease, may be applied in this manner, with good results.

Methods (*a*) and (*d*) are by far the best, and the selection of the method to use depends upon whether it is desirable to use a grease, or an oil.

Grease Retarders.—Retarders are made of copper wire gauze, perforated leather, perforated wood, or perforated copper sheets. These retarders are bent to conform to the surface of the journal, and are made to fit the entire width of the open well.

The grease is fed by means of a compression cup, or by other means, to the top of the retarder, where, due to the heat caused by the rubbing of the journal against the retarder, the grease is melted and flows over the back and through the holes onto the journal.

A very satisfactory retarder can be made from babbitt metal, as follows: The metal is cast in the form of a grid, bent to conform to the surface of the journal. The bottom surfaces of the cross-bars are grooved in the direction of rotation of the journal, to aid in the distribution of the lubricant. The cross-bars are also rounded off on the edge towards the direction of rotation, for the same reason that it is best to round off the edge of any oil groove. This allows the resulting wedge that is formed, to aid in the reduction of the scraping action between the retarder and the journal.

FRICTION LOSS IN THE UNITED STATES

Total Horse-power in the United States.—According to the last census, the total primary horse-power, produced in the United States, was 18,675,376. It is safe to estimate, that fully 50 per cent. of this power was wasted in overcoming unnecessary friction. If the average cost of producing a horse-power is assumed to be $20, the enormous cost of friction can thus be easily estimated.

OIL COOLERS

Uses of Oil Coolers.—Oil coolers are widely used for the cooling of oil used in the following-named apparatus:—

(*a*) Oil from steel quenching tanks.

(*b*) Electric transformer oils.

(*c*) Oil used for cooling the pistons of internal-combustion engines.

(*d*) Oils used in forced-feed circulating systems, particularly in connection with steam turbine bearing lubrication.

Oil Coolers.—The Schutte & Koerting Company, who are manufacturers of oil coolers, make the following recommendations:—

"It is better to use a large quantity of oil, circulating at a low temperature drop (without going below a certain minimum), than a small amount of oil circulating at a large temperature drop. It is better not to pass the oil through the bearings at too low a temperature, since cold oil is not as capable of absorbing and carrying away heat as is oil at a higher temperature. Fast circulation is a factor in the efficiency of a forced-feed lubricating system, as the warm oil from the bearings should be removed quickly, in order not to obstruct the incoming cooled oil from the cooler."

An important point in the construction of an oil cooler is the arrangement of the packing, since the responsibility of preventing any of the cooling water from mixing with the oil rests upon it.

The flow of oil is sluggish, as compared with water, and special means must be employed to effect an efficient and rapid means of transferring the heat in the oil to the water.

Fig. 113 shows a sectional view of the S. & K. Oil Cooler made by The Schutte & Koerting Company of Philadelphia. The tubes are held together in the form of a bundle. The water passages can be cleaned by simply removing the cover, without disconnecting any of the pipes, and the entire bundle can be removed. It is recommended that these

coolers be erected in a vertical position, in order that the flow of the liquids will be more uniform, and the sediment in the oil will settle to the bottom of the cooler, whence it can be easily removed.

Cooling of Quenching Tank Oil.—Fig. 114 shows the method of connecting the S. & K. Cooler in a circulating system for the purpose of

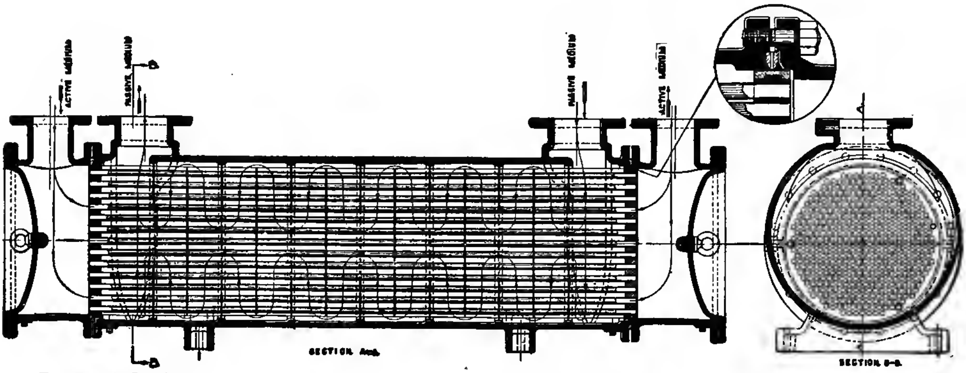

FIG. 113.—Sectional view of an S. & K. Oil Cooler, manufactured by The Schutte & Koerting Company.

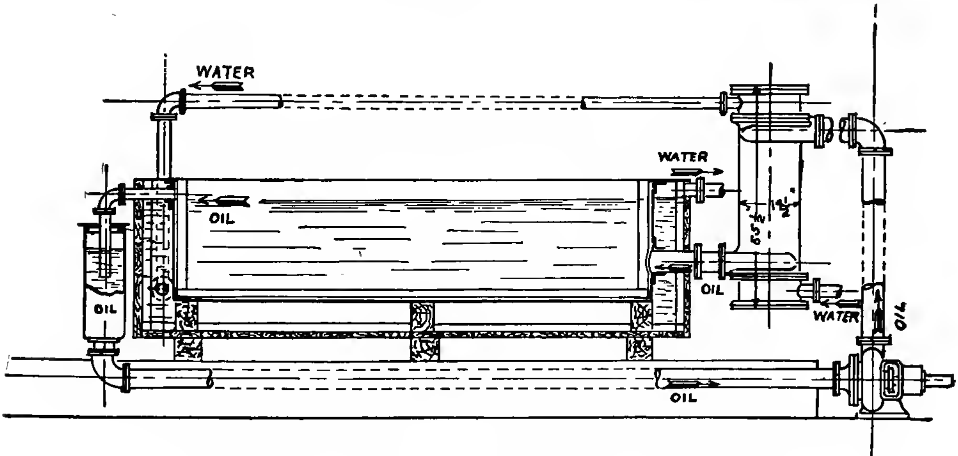

FIG. 114.—Method of cooling quenching tank oil with S. & K. Oil Cooler.

cooling oil used in quenching tanks, which are used for the heat treating of steel. This method will produce better results than can be obtained by the old method of cooling the oil by water ducts or coils, as is commonly done, as the circulation of the oil with the old method is very poor, particularly after the metal has been put in or removed from the tank.

Cooling of Transformer Oils.—When cooling the oil used in a transformer installation, it is preferable to use air as a cooling medium rather than water, as the possibility of the water getting into the oil and reducing its dielectric properties is very likely. Sometimes the cooling is effected by erecting a stack and drawing air through the cooler by natural draft, or the air may be forced through the cooler by means of a fan.

MANUFACTURE OF WASTE

Cotton waste, which is used for many purposes, is made by shredding rags, that are obtained from mills and other sources.

For certain grades of waste, such as colored waste, an oil known as "stock oil" is sprinkled over the rags, to prevent excessive dust and lint from rising during shredding and to weight the waste.

A typical "stock oil" would have the following general test:—

Flash	300 to 310° Fahr.	Viscosity about 55 to 65 at 100° Fahr.
Gravity	About 30° Baumé.	
Cold test	About 30° Fahr. (cloud).	
Color	Pale yellow.	

It is sometimes desirable to know the weight per gallon of stock oil, so that the amount of increase in the weight of the finished waste can be estimated, for various "mixes" of the oil. This weight can, of course, be determined, if the gravity of the oil is known.

Often the purchasers of waste limit the amount of oil that will be permited in its manufacture.

PLATE AND DIE OIL

When punching plates and for cutting washers, etc., from scrap plates, with stamping machines, a heavy oil is swabbed over the plate and on the dies, to furnish some lubrication for the cutting operation.

Usually a black lubricating oil, such as Summer Black Oil, is used for this purpose. (See Index for Summer Black Oil.)

EXAMINATION OF SAMPLES OF PETROLEUM PRODUCTS

When examining samples of petroleum products, with a view to determining the proper grade or product to offer in competition with the sample, the following properties of the sample should be determined:—

Cylinder Oil	*Black Oils*	*Engine or Spindle Oil*
Gravity	Gravity	Gravity
Flash (Open)	Flash (Open)	Flash (Open)
Flash (Closed	Pour (Cold Test)	Flash (Closed)
Pour	Per cent. Fatty Oil	Viscosity at 100° Fahr.
Viscosity at 212° Fahr.	Gasoline Test	Cold Test (Cloud)
Per cent. Fatty Oil	Viscosity at 130° Fahr.	Cold Test (Pour)
Color		Per cent. Fatty Oil
Gasoline Test	*Absorbent Oil*	Color
	Gravity	
Paraffine Wax	Flash Test (Open)	*Gasoline or Naphtha*
Per cent. Oil in Wax	Cold Test (Cloud)	Gravity
Color	De-emulsibility Figure	Color
Odor, if any		Overpoint
Melting-point	*Wool Oil, or Cutting Oil*	Per cent. at 158° Fahr.
	Gravity	Per cent. at 212° Fahr.
Petrolatum	Cold Test (Cloud)	Per cent. at 302° Fahr.
Consistency	Color	Per cent. at 320° Fahr.
Melting-point	Per cent. Fatty Oil	Dry-point
Color	Viscosity at 100° Fahr.	Flash

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Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @_____Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @____Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

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Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cent.

Brand	Color	Gravity Baume @ 60° F.	Viscosity Say. @ ____ Fahr.	Cold Test Fahr.	Flash Fahr.	Fire Fahr.	Compound Per Cen

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